

A preliminary survey of nocturnal ants, with novel modifications for collecting nocturnal arboreal ants

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Abstract

Ants were surveyed in a 100-m horizontal transect by employing three collecting techniques: leaf litter sifting and Winkler extraction, pitfall trapping, and beating of low vegetation. Ants were surveyed during the day and again at night to record the temporal behavior of the ants. In aggregate, 23 species of ants were collected only during the day, 24 species during the night, and 36 species during both day and night. There was a large overlap between diurnal and nocturnal ground-foraging and leaf-litter ant communities. On the other hand, the diurnal arboreal ant community seems to be distinct from the nocturnal arboreal ant community (Jaccard Distance = 0.85). Our results suggest that nocturnal arboreal ants are likely sources of new discoveries. The novel modifications we present here may help address this knowledge gap for ants and other nocturnal arboreal arthropods.

Keywords: *ant survey techniques, nocturnal arboreal ants, novel modification, temporal behaviour of ants.*

Received: 30 January 2020; Revised: 11 March 2020; Online: 16 March 2020

Introduction

The diversity of ants is surveyed using standardized quantitative collecting methods and traps, informing studies of ant communities and assembly rules. Ant surveys are usually conducted during the day. Collecting traps are typically deployed during the day and after some time, also retrieved during the day (Bestelmeyer *et al.* 2000; Delabie *et al.* 2000). Pitfall traps may be kept in place for 48-72 hours or longer, e.g., Lee and Guénard (2019). Malaise traps are usually deployed for several days, depending on how fast the collecting jars are filled by specimens, e.g., Lessard *et al.* (2007).

Leaf litter sifting and Winkler extraction, e.g., Lessard *et al.* (2007), and beating of low vegetation, e.g. Fisher (2002), are

usually performed during the day.

Safety, convenience, or habit may be the main reasons for collecting ants during the day. However, the daytime conduct of these surveys commonly overlooks the nocturnal activity of ants and biases the estimation of the diversity, richness, and assemblage of ants in favor of diurnally active ant species. Moreover, ecological and behavioral information may be lost by running traps for several days or collecting ants only during the day.

Nocturnal ant communities are poorly studied, although specimens of nocturnal ants are likely to be among the catch of long-running traps. Unfortunately, there is no infallible way to distinguish diurnal ants from nocturnal ants by

simply examining their morphology.

Rare ants may be more common at night. Wong and Yong (2017) observed the activities of a nest fragment of *Tyrannomyrmex rex* Fernandez, 2003 in a laboratory setting and inferred that the ant species may be nocturnal, based on the increased activity of the ants in the late afternoon. It is possible that nocturnal ants escape the leaf litter sifting and beating methods used by researchers.

In this paper, we introduce modifications to the typical ant collecting methods to accomplish the separate collection of diurnal and nocturnal ants. We also provide an initial data set and analysis of these data. We hope that this paper generates interest in the study of the temporal behavior of ants.

Materials and Methods

This study was conducted in March 2019 in Mt. Isarog Natural Park, in Del Rosario Village, Municipality of Pili, Camarines Sur Province, Luzon Island, Philippines.

The study site, at 600 meters above sea level, is a disturbed second-growth forest, dominated by a climbing bamboo, *Dinorchloa* sp. The area is part of the watershed of the Metro Naga Water District (MNWD). MNWD planted native and non-native trees within their administered watershed area. Field collections are covered by Gratuitous Permit R5-105 issued to DEMG by the Department of Environment and Natural Resources. Specimens are deposited in the Entomological Collection of the Museum of Natural History of the University of the Philippines Los Baños.

A modified ALL Protocol (Agosti and Alonso, 2000) was employed to sample the diurnal and nocturnal leaf litter-residing, ground-foraging, and arboreal ants. The ALL Protocol was abbreviated in length and modified with the addition of beating of low vegetation. Ten transect plots, 5-m radius, were established in a 100-m horizontal transect. Within each transect plot, the following collecting techniques were employed: leaf litter sifting and Winkler extraction for leaf litter ants; pitfall trapping for ground-foraging ants; and beating of low vegetation for arboreal ants. The techniques were performed during the day and again at night.

Leaf litter sifting and Winkler extraction: The leaf litter from a randomly placed 1-m² quadrat was sifted and the siftate placed in Winkler bags for 24 hours. Leaf litter was collected and sifted during the day and again at night, but from a different part of the plot. Leaf litter collected during the day was labelled with “LLD + plot number”, while leaf litter collected at night was labelled with “LLN + plot number”. These labels were placed in the collecting vial of the Winkler bag.

Pitfall trapping: A plastic cup (70 mm diameter, 85 mm depth) was placed in the ground, flush to the level of the ground. The cup was half-filled with a weak soapy solution (1-2 drops of liquid dish detergent in 1 litre clean water). For diurnal ants, the pitfall traps were in place from just before sunrise (local time 5:30 a.m.) to sunset (local time 6:00 p.m.). At the end of the trapping period, all the arthropods were collected and immediately placed in labelled 10ml vials containing fresh water. The soapy water in the traps was topped up to the previous level. The rinsed specimens were then transferred to labelled vials containing 95% ethanol. For nocturnal ants, the traps were in place from sunset (local time 6:00 p.m.) to just before sunrise (local time 5:30 a.m.). At the end of the trapping period, all the arthropods were collected and processed as with the diurnal pitfall catch. The diurnal pitfall collection was labelled with “PFD + plot number”, while the nocturnal pitfall collection was labelled with “PFN + plot number”. These labels were placed in the appropriate vials.

Beating of low vegetation: This method requires a team of 4-6 persons (Fig. 3), composed of: a striker, a person holding the beating sheet, a secretary to keep track of the branches struck, a person to hold the vial for the specimens, and others to manually collect the ants and bycatch from the beating sheet. During the establishment of the transect, five suitable (leafy and accessible) branches were selected within the plot. The branches were labelled with long pieces of flagging tape (~70 cm long) with the plot number and branch number, e.g., a branch labelled “1-1” refers to Plot 1, Branch 1. The long flagging tape allowed the team to locate the proper branches at night (compare Figs. 1 and 2). The labelling of the branches ensured that the

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branches sampled during the day would be sampled again at night. Each branch was struck five times over a 1-m² beating sheet. Ants and other arthropods that fell on the beating sheet were hand-collected and placed in a vial with 95% ethanol. The collections from the five branches in a plot were pooled into one labelled vial. The diurnal beating collection was labelled

“BD + plot number”, while the nocturnal beating collection was labelled “BN + plot number”. These labels were placed in the appropriate vials.

Two attempts to replicate this study at a different site of the same mountain were frustrated by bad weather.



Figure 1. Daytime view of branches of low vegetation tagged with long flagging tape. (Image courtesy: Emerson Y. Sy)



Figure 2. Nighttime view of same branches of low vegetation tagged with long flagging tape, at a slightly different angle. (Image courtesy: Emerson Y. Sy)



Figure 3. Team effort in collecting specimens from beating of low vegetation, at daytime. DEMG with grey shirt, PACB with dark blue shirt, LJVR as secretary, with notebook. (Image courtesy: Jasmin Meren).

Laboratory Work: The field ethanol was replaced with fresh 95% ethanol within 3 days after collection. The collections were sorted into morphospecies and placed in individual labelled vials. The morphospecies were then identified using available keys. The following keys were used in determining the genus of the specimens: Bolton (1994), Borowiec (2016), General and Alpert (2012), LaPolla *et al.* (2010), Schmidt and Shattuck (2014), and Ward *et al.* (2016). The following species-level references and keys were used for individual genera: *Anochetus* (Brown, 1978); *Crematogaster* (Hosoishi and Ogata, 2016, 2019); *Eurhopalothrix* (Taylor, 1968); *Lordomyrma* (Taylor, 2012); *Myopias* (Probst *et al.*, 2015); *Myrmicaria* (Zettel *et al.*, 2018); *Myrmoteras* (Zettel and Sorger, 2011); *Odontomachus* (Sorger and Zettel, 2011); *Odontoponera* (Yamane, 2009); *Parasyscia* (Brown, 1975; Borowiec, 2016); *Pheidole* (Eguchi, 2001); *Polyrhachis* subgenus keys: Dorow, 1995; Kohout, 2008; *Polyrhachis* (*Myrma*) *cyaniventris* species group: (Sorger and Zettel, 2010); *Ponera* (Wilson, 1957; Taylor, 1967; Leong *et al.*, 2019); *Pristomyrmex* (Wang, 2003; Zettel, 2006); *Recurvidris* (Bolton, 1992;

Zettel, 2008); *Strumigenys* (Bolton, 2000); *Technomyrmex* (Bolton, 2007); *Tetramorium* (Bolton, 1976, 1977); *Tetraponera* (Ward, 2001); *Vombisidris* (Bolton, 1991). We also referred to online resources to check our determinations (AntWeb, 2019; AntWiki, 2019). The Jaccard Similarity Index, $J = a/(a+b+c)$, where *a* is the number of species common to both collections and *b* and *c* are unique to each collection (Gotelli *et al.*, 2011) and its complement, the Jaccard Distance, $1-J$, were calculated. The Jaccard Indices were then subjected to cluster analysis to visualize the grouping of the transect plots. Dissimilarity cluster analysis was performed in R v. 3.5.2 (R Core Team, 2018) using the vegan package v. 2.5-5 (Oksanen *et al.*, 2019).

Results

A total of 1,253 ants were collected, representing 83 species in 40 genera and five subfamilies. In aggregate, 23 species were collected only during the day, 24 species were collected only during the night, while 36 species were collected during both day and night (Table 1).

Table 1. Aggregate list of ant species collected during diurnal and nocturnal sampling, using pitfall trapping, leaf litter sifting, and beating of low vegetation, Mt. Isarog Natural Park, San Isidro Village, Municipality of Pili, Province of Camarines Sur, Philippines. (sp. nr. = species near; cf. = compared with).

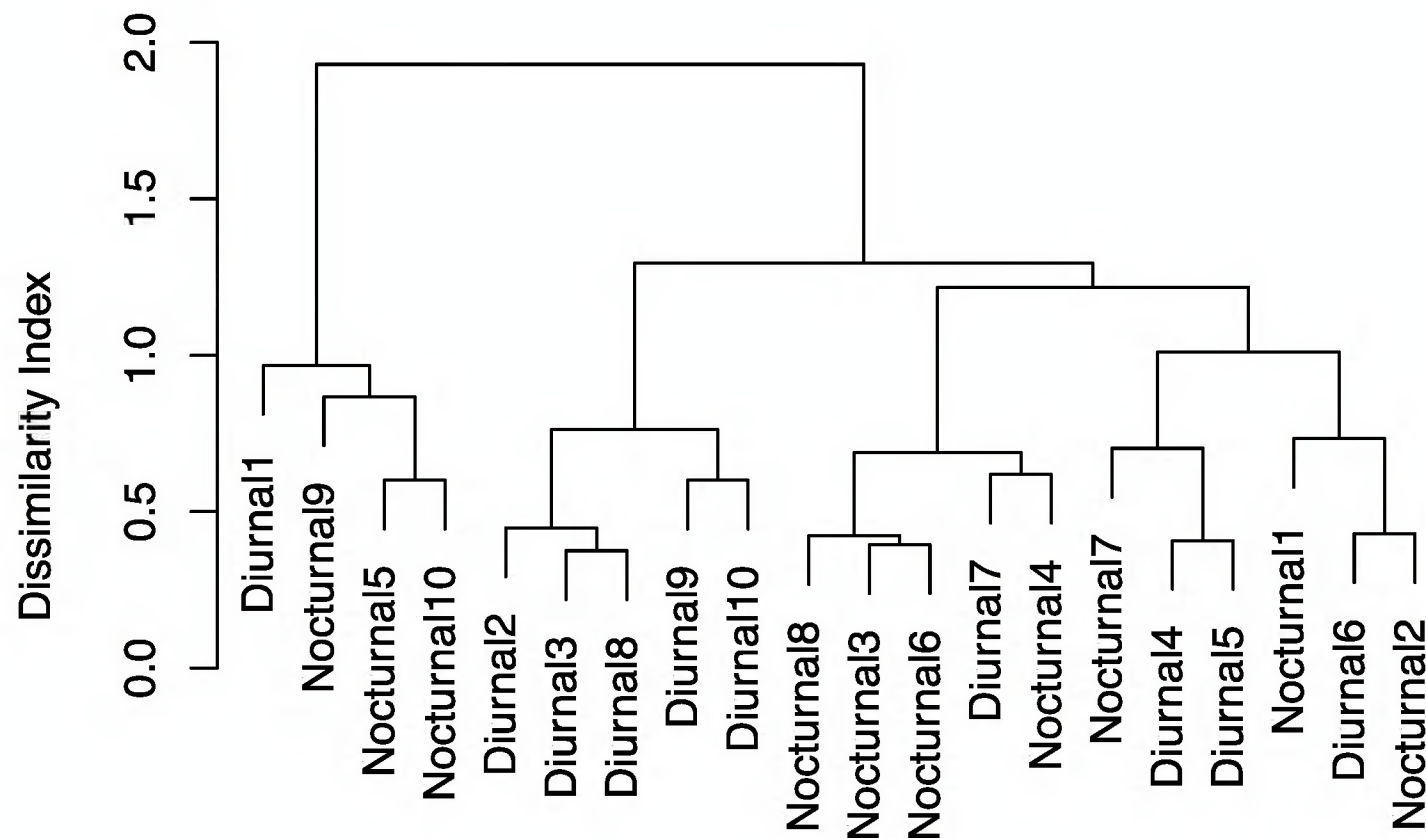
Diurnal Only (n=23)	Diurnal and Nocturnal (n=36)	Nocturnal Only (n=24)
<i>Camponotus</i> sp5	<i>Anochetus graeffei</i>	<i>Brachyponera</i> sp1
<i>Carebara</i> sp3	<i>Anochetus incultus</i>	<i>Camponotus</i> sp2
<i>Cataulacus catuvolcus</i>	<i>Brachyponera obscurans</i>	<i>Camponotus</i> sp3
<i>Centromyrmex feae</i>	<i>Camponotus</i> sp1	<i>Camponotus</i> sp4
<i>Colobopsis leonardi</i>	<i>Camponotus</i> sp6	<i>Colobopsis</i> sp3
<i>Colobopsis</i> sp1	<i>Carebara macca</i>	<i>Ectomomyrmex</i> sp1
<i>Crematogaster rothneyi</i>	<i>Carebara</i> sp1	<i>Hypoconera</i> cf. <i>opaciceps</i>
<i>Dilobocondyla</i> sp1	<i>Carebara</i> sp2	<i>Lordomyrma diwata</i>
<i>Lepisiota</i> cf. <i>chapmani</i>	<i>Colobopsis horrens</i>	<i>Myopias bidens</i>
<i>Leptogenys diminuta</i>	<i>Crematogaster philippinensis</i>	<i>Myrmecina</i> sp1
<i>Odontoponera denticulata</i>	<i>Dolichoderus thoracicus</i>	<i>Paraparatrechina</i> sp2
<i>Parasyscia rufithorax</i>	<i>Eurhopalothrix philippina</i>	<i>Pheidole cariniceps</i>
<i>Pheidole</i> sp. nr. <i>bugi</i>	<i>Hypoconera</i> sp1	<i>Pheidole quadricuspis</i>
<i>Polyrhachis cyaniventris</i>	<i>Hypoconera</i> sp2	<i>Pheidole</i> sp1
<i>Polyrhachis parabiatica</i>	<i>Myrmecaria</i> sp1	<i>Pheidole tjibodana</i>
<i>Polyrhachis saevissima</i>	<i>Myrmoteras mcarthuri</i>	<i>Polyrhachis</i> cf. <i>hippomanes</i>
<i>Ponera</i> sp. nr. <i>wui</i>	<i>Odontomachus banksi</i>	<i>Polyrhachis illaudata</i>
<i>Recurvidris</i> sp1	<i>Paraparatrechina</i> sp1	<i>Strumigenys eggersi</i>
<i>Strumigenys pedunculata</i>	<i>Pheidole aglae</i>	<i>Strumigenys euryale</i>
<i>Sylophopsis</i> sp2	<i>Pheidole fervens</i>	<i>Strumigenys</i> sp1
<i>Temnothorax</i> sp1	<i>Pheidole</i> cf. <i>hortensis</i>	<i>Strumigenys</i> cf. <i>synchysis</i>
<i>Tetramorium</i> sp1	<i>Pheidole kikutai</i>	<i>Tapinoma</i> sp1
<i>Tetraponera allaborans</i>	<i>Pheidole</i> sp. nr. <i>parva</i>	<i>Tetramorium pacificum</i>
	<i>Pheidole rabo</i>	<i>Vombisidris</i> sp1
	<i>Pheidole</i> sp. nr. <i>sayapensis</i>	
	<i>Plagiolepis</i> sp1	
	<i>Ponera</i> sp1	
	<i>Prenolepis</i> sp1	
	<i>Pristomyrmex collinus</i>	
	<i>Solenopsis</i> sp1	
	<i>Strumigenys koningsbergeri</i>	
	<i>Strumigenys mirifica</i>	
	<i>Sylophopsis</i> sp1	
	<i>Technomyrmex sundaicus</i>	
	<i>Tetramorium aspersum</i>	
	<i>Tetramorium khnum</i>	

Leaf litter ants: Fifty-one species were collected from the leaf litter (Table 2). Twelve species were collected only during the day, 15 species were collected only during the night, while 24 species were

collected from both day and night sampling of the leaf litter. Figure 4 illustrates the dissimilarity index between diurnal and nocturnal leaf litter collections.

Table 2. List of leaf litter-inhabiting ant species encountered during diurnal and nocturnal leaf litter sifting (LL) and Winkler extraction, Mt. Isarog Natural Park, San Isidro Village, Municipality of Pili, Province of Camarines Sur, Philippines. (sp. nr. = species near).

Diurnal LL (n=12)	Diurnal and Nocturnal LL (n=24)	Nocturnal LL (n=15)
<i>Carebara</i> sp3	<i>Anochetus graeffei</i>	<i>Brachyponera</i> sp1
<i>Centromyrmex feae</i>	<i>Anochetus incultus</i>	<i>Camponotus</i> sp1
<i>Colobopsis horrens</i>	<i>Brachyponera obscurans</i>	<i>Hypoponera opaciceps</i>
<i>Parasyscia rufithorax</i>	<i>Carebara macca</i>	<i>Lordomyrma diwata</i>
<i>Pheidole hortensis</i>	<i>Carebara</i> sp1	<i>Myopias bidens</i>
<i>Pheidole kikutai</i>	<i>Carebara</i> sp2	<i>Odontomachus banksi</i>
<i>Ponera</i> sp. nr. <i>wui</i>	<i>Crematogaster philippinensis</i>	<i>Pheidole aglae</i>
<i>Recurvidris</i> sp1	<i>Eurhopalothrix philippina</i>	<i>Pheidole cariniceps</i>
<i>Strumigenys mirifica</i>	<i>Hypoponera</i> sp1	<i>Pheidole fervens</i>
<i>Strumigenys pedunculata</i>	<i>Hypoponera</i> sp2	<i>Pheidole tjibodana</i>
<i>Syllophopsis</i> sp2	<i>Myrmecaria</i> sp1	<i>Strumigenys eggersi</i>
<i>Temnothorax</i> sp1	<i>Myrmoteras mcarthuri</i>	<i>Strumigenys euryale</i>
	<i>Paraparatrechina</i> sp1	<i>Strumigenys synchysis</i>
	<i>Pheidole</i> sp. nr. <i>sayapensis</i>	<i>Tetramorium aspersum</i>
	<i>Pheidole rabo</i>	<i>Tetramorium pacificum</i>
	<i>Plagiolepis</i> sp1	
	<i>Ponera</i> sp1	
	<i>Prenolepis</i> sp1	
	<i>Pristomyrmex collinus</i>	
	<i>Solenopsis</i> sp1	
	<i>Strumigenys koningsbergeri</i>	
	<i>Syllophopsis</i> sp1	
	<i>Technomyrmex sundaicus</i>	
	<i>Tetramorium khnum</i>	



Leaf Litter Plots

Figure 4. Dendrogram illustrating the dissimilarity index between diurnal and nocturnal leaf litter collections, by transect plot. Numbers refer to the transect plot.

Ground-foraging ants: Twenty-one species were collected from pitfall traps (Table 3). Four species were found only during the day, eight species were collected only at night, while nine

species were collected from both day and night pitfall trapping. Figure 5 illustrates the dissimilarity index between diurnal and nocturnal pitfall collections.

Table 3. List of ground-foraging ant species encountered during diurnal and nocturnal pitfall trapping (PF), Mt. Isarog Natural Park, San Isidro Village, Municipality of Pili, Province of Camarines Sur, Philippines. (sp. nr. = species near).

Diurnal PF (n=4)	Diurnal and Nocturnal PF (n=9)	Nocturnal PF (n=8)
<i>Camponotus</i> sp5	<i>Brachyponera obscurans</i>	<i>Ectomomyrmex</i> sp1
<i>Dolichoderus thoracicus</i>	<i>Carebara macca</i>	<i>Eurhopalothrix philippina</i>
<i>Odontoponera denticulata</i>	<i>Crematogaster philippinensis</i>	<i>Myrmecina</i> sp1
<i>Recurvidris</i> sp1	<i>Hypoconera</i> sp2	<i>Pheidole cariniceps</i>
	<i>Myrmecaria</i> sp1	<i>Pheidole rabo</i>
	<i>Odontomachus banksi</i>	<i>Strumigenys mirifica</i>
	<i>Pheidole hortensis</i>	<i>Strumigenys</i> sp1
	<i>Pheidole</i> sp. nr. <i>parva</i>	<i>Technomyrmex sondaicus</i>
	<i>Solenopsis</i> sp1	

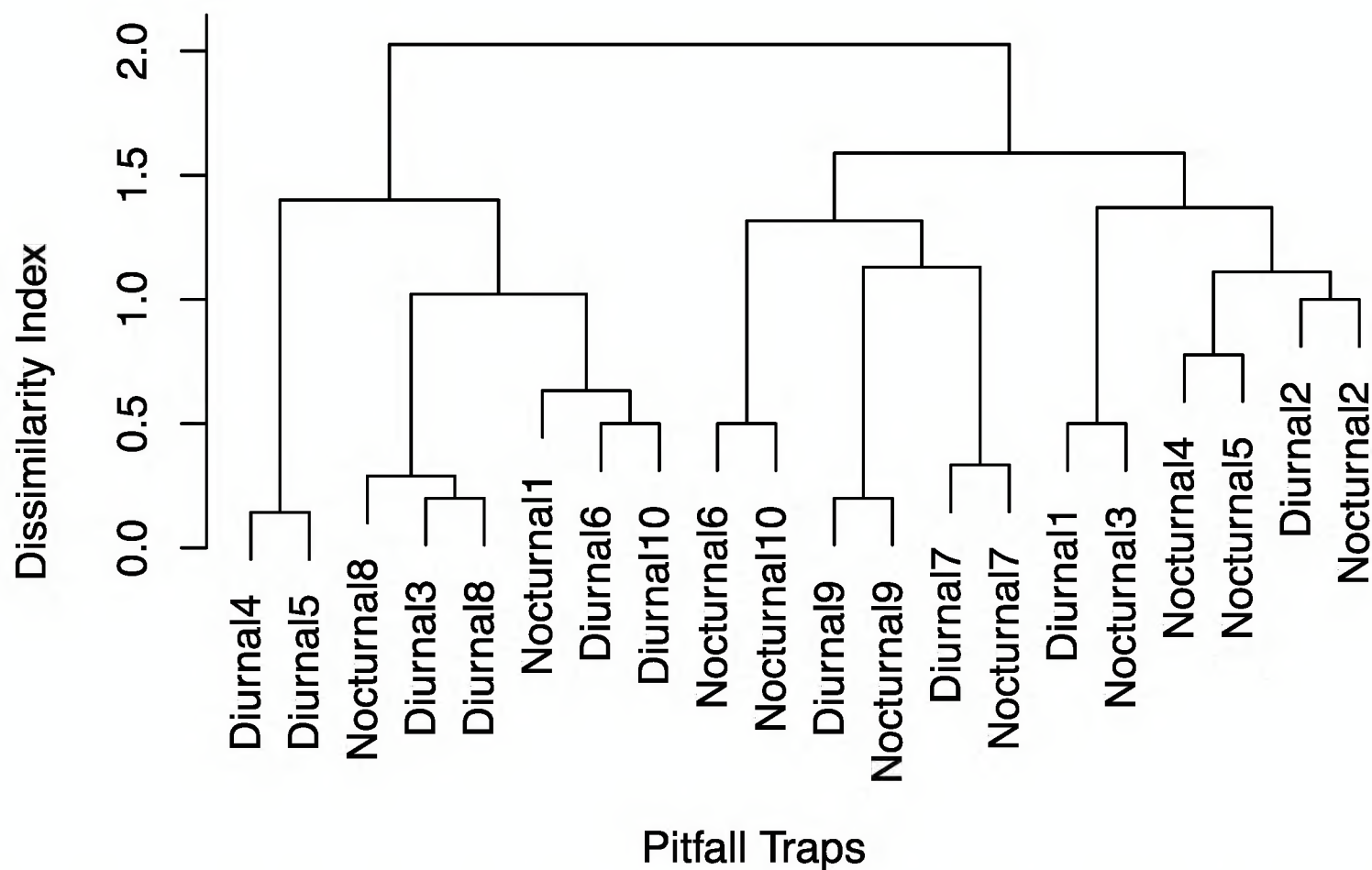


Figure 5. Dendrogram illustrating the dissimilarity index between diurnal and nocturnal pitfall collections, by transect plot. Numbers refer to the transect plot.

Table 4. List of arboreal ant species encountered during diurnal and nocturnal beating (BG) of low vegetation, Mt. Isarog Natural Park, San Isidro Village, Municipality of Pili, Province of Camarines Sur, Philippines. (sp. nr. = species near; cf. = compared with).

Diurnal BG (n=18)	Diurnal/Nocturnal BG (n=5)	Nocturnal BG (n=14)
<i>Camponotus</i> sp1	<i>Camponotus</i> sp6	<i>Camponotus</i> sp2
<i>Camponotus</i> sp5	<i>Colobopsis horrens</i>	<i>Camponotus</i> sp3
<i>Cataulacus catuvolcus</i>	<i>Crematogaster philippinensis</i>	<i>Camponotus</i> sp4
<i>Colobopsis leonardi</i>	<i>Dolichoderus thoracicus</i>	<i>Colobopsis</i> sp3
<i>Colobopsis</i> sp1	<i>Pheidole aglae</i>	<i>Paraparatrechina</i> sp1
<i>Crematogaster rothneyi</i>		<i>Paraparatrechina</i> sp2
<i>Dilobocondyla</i> sp1		<i>Pheidole cariniceps</i>
<i>Lepisiota</i> cf. <i>chapmani</i>		<i>Pheidole quadricuspis</i>
<i>Leptogenys diminuta</i>		<i>Plagiolepis</i> sp1
<i>Myrmecaria</i> sp1		<i>Polyrhachis hippomanes</i>
<i>Pheidole</i> sp. nr. <i>bugi</i>		<i>Polyrhachis illaudata</i>
<i>Pheidole kikutai</i>		<i>Prenolepis</i> sp1
<i>Polyrhachis cyaniventris</i>		<i>Tapinoma</i> sp1
<i>Polyrhachis parabiatica</i>		<i>Vombisidris</i> sp1
<i>Polyrhachis saevissima</i>		
<i>Tetramorium aspersum</i>		
<i>Tetramorium</i> sp1		
<i>Tetraponera allaborans</i>		

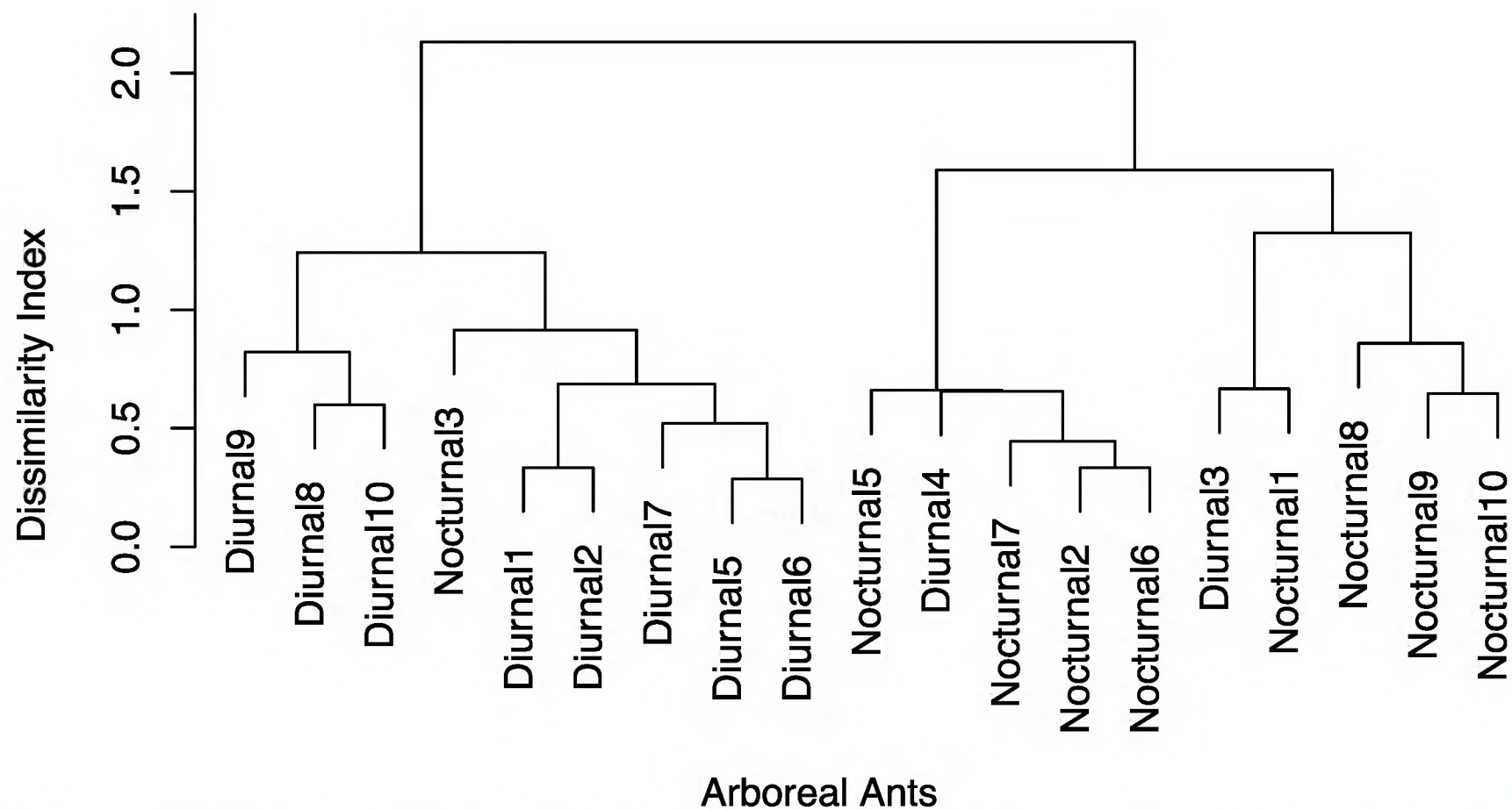


Figure 6. Dendrogram illustrating the dissimilarity index between diurnal and nocturnal beating collections, by transect plot. Numbers refer to the transect plot.

Arboreal ants: Thirty-seven species were collected from beating of low vegetation (Table 4). Eighteen species were found only during the day, 14 species were collected only at night, while 5 species were collected from both day and night beating of low vegetation. Figure 6 illustrates the dissimilarity index between diurnal and nocturnal beating collections.

Comparison between diurnal and nocturnal collections

Jaccard indices and Jaccard distance values were computed for the collections by method as well as for the pooled collection (Table 5). The most distinct ant communities were recorded by the Beating method, while the most similar communities were recorded by the leaf litter sifting.

Table 5. Jaccard similarity indices and Jaccard distance values of the diurnal and nocturnal ant communities, by collecting method and pooled collection.

Collection Method	Jaccard Index	Jaccard Distance
Leaf litter sifting	0.47	0.53
Pitfall trapping	0.43	0.57
Beating	0.15	0.85
Pooled collection	0.43	0.57

Discussion

The novel modifications to the beating technique involve: (a) forming a team and assigning a “secretary”, a team member to keep track of which branches have been sampled (Fig. 3); and (b) labeling the branches with long, numbered flagging tape. Having a “secretary” prevents confusion and mistakes in sampling the

labelled branches. Labeling the branches allows not only finding the branches at night and keeping track of what had been sampled, but more importantly, the direct comparison of the arboreal ants occupying the low vegetation during the day and at night. Exactly the same branches were sampled during diurnal and nocturnal sampling (Figs. 1 and 2). Since

branches are used by ants as highways, sampling the same branches during the day and at night captures the change of occupancy of the highway.

The results of this preliminary study clearly suggest the presence of a nocturnal subset of the ant community of a forest patch. All three collecting methods support this finding, even though there is a large overlap between diurnal and nocturnal leaf litter and ground-foraging ant communities.

The ants collected by pitfall trapping and leaf litter sifting showed a large overlap of species, thus there may not be enough reason to particularly sample the nocturnal subset of ground-foraging and leaf litter-inhabiting ants.

The arboreal ants, however, exhibit the largest difference between the diurnal and nocturnal assemblages (Jaccard distance = 0.85). This value implies the existence of a distinct assemblage of nocturnal arboreal ants. It is believed that efforts to sample the nocturnal arboreal ants may be rewarded with discoveries of new species and the capture of the temporal behavior of known species.

In sum, the presence of a distinct nocturnal subset of the ant community of a forest patch suggests that the extra effort to collect this subset would be rewarded with discoveries or a better understanding of the ant community as a whole. Nocturnal leaf litter ants may include species that are rare in collections, such as species of the genus *Tyrannomyrmex* (AntWiki, 2019). Of particular interest is the subset of nocturnal arboreal ants, including *Vombisidris*, because these ants are poorly studied.

Beetles, spiders, and other arthropods, e.g., Archaeognatha, were collected by these methods as by-catch but the specimens were pooled. It is possible that these methods may also capture the temporal behavior of other insects and arthropods.

Acknowledgments

We thank the Metro Naga Water District for allowing access to their watershed and providing us with their field personnel for porters, guides, and cooks. We also thank the Department of Environment and Natural Resources, Region V for issuing a Gratuitous

Permit (GP# R5-105) to DEMG. We especially appreciate the assistance in the field by Arvin C. Diesmos, Jasmin C. Meren, Yñigo C. del Prado, Rolly C. Urriza, Roylan C. Urriza, and Emerson Y. Sy. We are also grateful to Emerson Y. Sy and Jasmin C. Meren for providing the field images. We also thank Nicole Bechayda for sorting the ant specimens to genus. And we are grateful to our respective institutions for allowing us to conduct field work. This work was partly funded by the UP System Enhanced Creative Work and Research Grant (ECWRG 2018-1-013) to DEMG.

References

- Agosti, D. and Alonso, L.E. 2000. The ALL Protocol: a standard protocol for the collection of ground-dwelling ants. *In*: D. Agosti, J.D. Majer, L.E. Alonso, and T.R. Schultz (eds.), *Ants: Standard Methods for Measuring and Monitoring Biodiversity*, Washington D. C., USA: Smithsonian Institution Press, 204-206.
- AntWeb. 2019. <<http://www.antweb.org>>, accessed on 28 October 2019.
- AntWiki. 2019. <<http://www.antwiki.org>>, accessed on 28 October 2019.
- Bestelmeyer, B.T., Agosti, D., Alonso, L.E., Brandão, C.R.F., Brown, W.L.Jr., Delabie, J.H.C. and Silvestre, R. 2000. Field techniques for the study of ground-dwelling ants: an overview, description, and evaluation. *In*: D. Agosti, J.D. Majer, L.E. Alonso and T.R. Schultz, (eds.), *Ants: Standard Methods for Measuring and Monitoring Biodiversity*, Washington D. C., USA: Smithsonian Institution Press, 122-144.
- Bolton, B. 1976. The ant tribe Tetramoriini. Constituent genera, review of smaller genera and revision of *Triglyphothrix* Forel. *Bulletin of the British Museum (Natural History) (Entomology)* 34: 281-379.
- Bolton, B. 1977. The ant tribe Tetramoriini. The genus *Tetramorium* Mayr in the Oriental and Indo-Australian regions, and in Australia. *Bulletin of the British Museum (Natural History) (Entomology)* 36: 67-151.
- Bolton, B. 1991. New myrmicine ant genera from the Oriental region. *Systematic Entomology* 16: 1-13.

- Bolton, B. 1992. A review of the ant genus *Recurvidris*, a new name for *Trigonogaster* Forel. *Psyche* 99: 35-48.
- Bolton, B. 1994. Identification guide to the ant genera of the world. Cambridge, MA, USA: Harvard University Press. 222 pp.
- Bolton, B. 2000. The ant tribe Dacetini. *Memoirs of the American Entomological Institute* 65: 1-1028.
- Bolton, B. 2007. Taxonomy of the dolichoderine ant genus *Technomyrmex* Mayr based on the worker caste. *Contributions of the American Entomological Institute* 35(1): 1-150.
- Borowiec, M.L. 2016. Generic revision of the ant subfamily Dorylinae (Hymenoptera, Formicidae). *ZooKeys* 608: 1-280. <http://dx.doi.org/10.3897/zookeys.608.9427>
- Brown, W.L.Jr. 1975. Contributions toward a reclassification of the Formicidae. 5. Ponerinae, tribes Platythyreini, Cerapachyini, Cyldromyrmecini, Acanthostichini, and Aenictogitini. *Search Agriculture, 5, Entomology (Ithaca)* 15: 1-115.
- Brown, W.L.Jr. 1978. Contributions toward a reclassification of the Formicidae. Part 6. Ponerinae, tribe Ponerini, subtribe Odontomachiti. Section B. Genus *Anochetus* and bibliography. *Studia Entomologica (N.S.)* 20: 549-652.
- Delabie, J.H.C., Fisher, B.L., Majer, J.D. and Wright, I.W. 2000. Sampling effort and choice of methods. In: D. Agosti, J.D. Majer, L.E. Alonso, and T. R. Schultz (eds.), *Ants: Standard Methods for Measuring and Monitoring Biodiversity*, Washington D. C., USA: Smithsonian Institution Press, 145-154.
- Dorow, W.H.O. 1995. Revision of the ant genus *Polyrhachis* Smith, 1857 on subgenus level with keys, checklist of species and bibliography. *Courier Forschungsinstitut Senckenberg* 185: 1-113.
- Eguchi, K. 2001. A revision of the Bornean species of the ant genus *Pheidole*. *Tropics Monograph Series* 2: 1-154.
- Fisher, B.L. 2002. Ant diversity patterns along an elevational gradient in the Réserve Spéciale de Manongarivo, Madagascar. *Boissiera* 59: 311-328.
- General, D.M. and Alpert, G.D. 2012. A synoptic review of the ant genera (Hymenoptera: Formicidae) of the Philippines. *ZooKeys* 200: 1-111. <http://dx.doi.org/10.3897/zookeys.200.2447>
- Gotteli, N.J., Ellison, A.M., Dunn, R.R. and Sanders, N.J. 2011. Counting ants (Hymenoptera: Formicidae): biodiversity sampling and statistical analysis for myrmecologists. *Myrmecological News* 15: 13-19.
- Hosoishi, S. and Ogata, K. 2016. Systematics and biogeography of the ant genus *Crematogaster* Lund subgenus *Orthocrema* Santschi in Asia (Hymenoptera: Formicidae). *Zoological Journal of the Linnean Society* 176: 547-606. <http://doi.org/10.1111/zoj.12330>
- Hosoishi, S. and Ogata, K. 2019. Cryptic diversity in the widespread Asian Ant *Crematogaster rothneyi* (Hymenoptera: Formicidae) inferred from morphological and genetic evidence. *Zoological Studies* 58(11): 1-15. <http://doi.org/10.6620/ZS.2019.58-11>
- Kohout, R.J. 2008. A review of the *Polyrhachis* ants of Sulawesi with keys and descriptions of new species. (Hymenoptera: Formicidae: Formicinae). *Memoirs of the Queensland Museum* 52(2): 255-317.
- LaPolla, J.S., Brady, S.G. and Shattuck, S.O. 2010. Phylogeny and taxonomy of the *Prenolepis* genus-group of ants (Hymenoptera: Formicidae). *Systematic Entomology* 35: 118-131.
- Lee, R.H. and Guénard, B. 2019. Choices of sampling method bias functional components estimation and ability to discriminate assembly mechanisms. *Methods in Ecology and Evolution* 2019: 1-12. <https://doi.org/10.1111/2041-210X.13175>
- Leong, C.M., Guénard, B., Shiao, S.F. and Lin, C.C. 2019. Taxonomic revision of the genus *Ponera* Latreille, 1804 (Hymenoptera: Formicidae) of Taiwan and Japan, with a key to East Asian species. *Zootaxa* 4594(1): 1-86. <https://doi.org/10.11646/zootaxa4594.1.1>
- Lessard, J-P., Dunn, R.R., Parker, C.P. and Sanders, N.J. 2007. Rarity and diversity in

- forest ant assemblages of Great Smoky Mountains National Park. Southeastern Naturalist Special Issue 1: 215-228.
- Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Szoecs, E. and Wagner, H. 2019. vegan: Community Ecology Package. R package version 2.5-5. <https://CRAN.R-project.org/package=vegan>.
- Probst, R.S., Guénard, B. and Boudinot, B.E. 2015. Toward understanding the predatory ant genus *Myopias* (Formicidae: Ponerinae), including a key to global species, male-based generic diagnosis, and new species description. Sociobiology 101 62(2): 192-212. <https://doi.org/10.13102/sociobiology.v62i2.192-212>
- R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: <https://www.R-project.org/>.
- Schmidt, C.A. and Shattuck, S.O. 2014. The higher classification of the ant subfamily Ponerinae (Hymenoptera: Formicidae), with a review of ponerine ecology and behavior. Zootaxa 3817(1): 1-242. <http://dx.doi.org/10.11646/zootaxa.3817.1.1>
- Sorger, D.M. and Zettel, H. 2010. Taxonomic additions to the *Polyrhachis* (*Myrma*) *cyaniventris* species group (Insecta: Hymenoptera: Formicidae). Annalen des Naturhistorischen Museums in Wien, Serie B 111: 31-36.
- Sorger, D.M. and Zettel, H. 2011. On the ants (Hymenoptera: Formicidae) of the Philippine Islands: V. The genus *Odontomachus* Latrielle, 1804. Myrmecological News 14: 141-163.
- Taylor, R.W. 1967. A monographic revision of the ant genus *Ponera* Latrielle. Pacific Insects Monograph 13: 1-112.
- Taylor, R.W. 1968. Notes on the Indo-Australian basicerotine ants (Hymenoptera: Formicidae). Australian Journal of Zoology 16: 333-348.
- Taylor, R.W. 2012. Ants of the genus *Lordomyrma* Emery (2) The Japanese *L. azumai* (Santschi) and six new species from India, Viet Nam and the Philippines (Hymenoptera: Formicidae: Myrmicinae). Zootaxa 3282: 45-60.
- Wang, M. 2003. A monographic revision of the ant genus *Pristomyrmex*. Bulletin of the Museum of Comparative Zoology 157: 383-542.
- Ward, P.S. 2001. Taxonomy, phylogeny and biogeography of the ant genus *Tetraponera* in the Oriental and Australian regions. Invertebrate Taxonomy 15: 589-665.
- Ward, P.S., Blaimer, B.B. and Fisher, B.L. 2016. A revised phylogenetic classification of the ant subfamily Formicinae (Hymenoptera: Formicidae), with resurrection of the genera *Colobopsis* and *Dinomyrmex*. Zootaxa 4072(3): 343-357. <http://doi.org/10.11646/zootaxa.4072.3.4>
- Wilson, E.O. 1957. The *tenuis* and *selenophora* groups of the ant genus *Ponera*. Bulletin of the Museum of Comparative Zoology at Harvard College 116: 355-386.
- Wong, M.K.L. and Yong, G.W.J. 2017. Notes on the habitat and biology of the rare ant genus *Tyrannomyrmex* (Fernandez, 2003). Asian Myrmecology 9 e009007: 1-4.
- Yamane, S. 2009. *Odontoponera denticulata* (F. Smith) (Formicidae: Ponerinae), a distinct species inhabiting disturbed areas. Ari 32: 1-8.
- Zettel, H. 2006. On the ants of the Philippine Islands: I. The genus *Pristomyrmex* Mayr, 1866. Myrmecologische Nachrichten 8: 59-68.
- Zettel, H. 2008. On the ants of the Philippine Islands: III. The genus *Recurvidris* Bolton. Linzer Biologische Beiträge, 40/1: 891-895.
- Zettel, H., Laciny, A., Balàka, P. and General, D.E.M. 2018. On the taxonomy of *Myrmecaria* Saunders, 1842 (Hymenoptera: Formicidae) in the Philippines. Raffles Bulletin of Zoology 66: 610-623.
- Zettel, H. and Sorger, D.M. 2011. New *Myrmoteras* ants from the southeastern Philippines. Raffles Bulletin of Zoology 59: 61-67.

First record of *Schedorhinotermes makassarensis* Kemner (Isoptera: Rhinotermitidae) from India

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Abstract

The present study reports *Schedorhinotermes makassarensis* Kemner, 1934 (Rhinotermitidae) for the first time in India, from Great Nicobar Island. Earlier the species was known only from Indonesia. A dichotomous identification key to all the 8 species of *Schedorhinotermes* Silvestri 1909 present in India is provided based on both soldier major and soldier minor castes.

Keywords: *Schedorhinotermes makassarensis*, Termite, India, identification key, dimorphic, Great Nicobar Island.

Received: 30 June 2019; Revised: 26 May 2020; Online: 15 June 2020

Introduction

Termites are truly social insects with distinct division of labour among different castes- soldiers, workers and imagoes (Noirot, 2000). They play a major role in cellulose decomposition and are thereby of immense ecological significance (Pearce, 1997). Although their feeding habit helps in recycling nutrients in the ecosystem, they also damage structural wood, furniture and wood panels (Su and Scheffrahn, 1990). Subterranean termites having association with soil are the most widespread and destructive (Potter, 1997; Su and Scheffrahn, 1998). Genus *Schedorhinotermes* is such a subterranean termite genus. Silvestri (1909) fixed *Schedorhinotermes* as a subgenus of *Rhinotermes*, with type species *R. intermedius* Brauer, 1865 from Australia. It continued to remain as a subgenus (Holmgren, 1911, 1913; Hill, 1942), till Snyder (1949) raised it to generic status. It is phylogenetically closest to *Rhinotermes* Hagen, 1858 (Krishna *et al.*, 2013). Globally, as many as 34 species have been described under the genus- 22 spp. from Oriental and 7 spp. from India are known, till date (Krishna *et al.*, 2013), the species being *S. longirostris* (Brauer, 1866), *S. eleanorae* Roonwal and Bose, 1970, *S. tiwarii* Roonwal and Thakur, 1963, *S. nancowriensis* Maiti and

Chakraborty, 1994, *S. medioobscurus* (Holmgren, 1914), *S. translucens* (Haviland, 1898) and *S. malaccensis* (Holmgren, 1913).

The soldier caste of all *Schedorhinotermes* species are dimorphic, with major and minor forms, the minor is common, and known for all the species present in India (Roonwal and Chhotani, 1989). Genus *Schedorhinotermes* being subterranean, nests in root stumps, weak trees and also in buried timber. They feed on woods, leaves, barks and grasses; the cellulose is digested by their intestinal protozoan symbionts. Two species in India, under this genus, *S. translucens* (Haviland) and *S. longirostris* (Brauer) are minor pests (Krishna *et al.*, 2013). The present study reports, *S. makassarensis* Kemner for the first time in India, from Great Nicobar Island. The species originally described from Indonesia, was known only from the type locality, Celebes, Macassar till date. All the 8 species from India are keyed and a redescription of *S. makassarensis*, along with digital images are provided.

Materials and Methods

1 vial with 2 soldier major, 2 soldier minor and 1 worker, collected from Great Nicobar Island were studied. The specimens

were preserved in 70% alcohol. All studies were made using the Leica 205-A stereomicroscope fitted with DFC 500 camera. The identification and measurements were taken in accordance with Maiti (2006). Morphological terminology for describing soldier follows Roonwal and Chhotani (1989) and Maiti (2006). The specimens are deposited in the National Zoological Collection (NZC) of Zoological Survey of India (ZSI), Kolkata.

Taxonomy:

Schedorhinotermes makassarensis Kemner, 1934

Syn: *Rhinotermes* (*Schedorhinotermes*) *longirostris* Oshima, 1914: 562.

Rhinotermes (*Schedorhinotermes*) *translucens* Holmgren, 1913: 83.

Redescription:

Soldier (Major) (Fig. 1)

Head yellowish to light brown, subsquarish, lateral margins slightly outcurved and posterior margin rounded. Head in dorsal view depressed behind antennae (Fig. 2). Lateral margin of head angularly rounded. Fontanelle round with furrow running in front.

Labrum broad with wavy anterior margin with minute hairs. Mandibles short and robust; left mandible with two and right mandible with a single marginal tooth. Antennae 15-16 segmented; segment 2 shorter than 3rd, 4th shortest. Postmentum waist not much narrow; sufficiently more than half of its maximum width (Fig. 3). Pronotum narrower than head, with outcurved anterior margin and medially emarginate posterior margin.

Soldier (Minor) (Fig. 4)

Head paler and much smaller than of soldier (major) and oval in shape (Fig. 5). Labrum bilobed with fringes of hair along anterior margin, very long almost reaching to tip of mandibles. Mandibles thin and delicate, left mandible with two and right mandible with a single marginal tooth (Fig. 5 and 6; tips broken). Postmentum and pronotum similar to soldier (major), but smaller in size (Fig. 6).

Measurements

Measurements are provided for soldier (major) and soldier (minor) from present study and from Maiti (2006) (Table 1).

Table 1: Measurements (in mm) of soldiers of *S. makassarensis* Kemner

Measurements of soldiers from present study (n=2)			Measurements of soldiers as per Maiti (2006)	
Characters	Soldier (major)	Soldier (minor)	Soldier (major)	Soldier (minor)
Length of head to lateral base of mandibles	1.34	0.80	1.34-1.52	0.80-0.92
Max. width of head	1.33	0.77	1.38-1.50	0.77-0.81
Head Index (width/length)	0.99	0.96	0.99-1.00	-
Length of mandible	0.84	0.46	0.84	-
Head-mandibular length index (mandible length/head length)	0.62	0.58	0.54	-
Median length of postmentum	1.00	0.57	-	0
Max. width of postmentum	0.42	0.28	0.28*	0.28
Min. width of postmentum	0.26	0.21	-	-
Max. length of pronotum	-	-	0.49-0.55	0.37-0.40
Max. width of pronotum	-	-	0.67-0.72	0.54-0.57

*both the major and minor postmentum cannot have the same width, the value given is probably an error.



Figures 1-6. *Schedorhinotermes makassarensis* Kemner: **1.** Soldier Major: whole body; **2.** Soldier Major: Dorsal view of head; **3.** Soldier Major: Ventral view of head; **4.** Soldier Minor: whole body; **5.** Soldier Minor: Dorsal view of head; **6.** Soldier Minor: Ventral view of head.

Materials examined: 1 vial of specimens Reg. No. 4707/H11: 2 soldier major, 2 soldier minor and 1 worker; INDIA: Andaman and Nicobar: Great Nicobar Island: East-West Road (07°01.079' N 93°55.323' E): 20.viii. 2016, Coll. C. Sivaperuman.

Discussions

From Andaman and Nicobar islands, a total of 36 species of termites have been reported with 27 spp. from Andaman and 25 spp. in Nicobar (Sengupta *et al.*, 2018). This study adds one more species, viz., *S. makassarensis* to the list and genus *Schedorhinotermes* is now known from India

by 8 species. A global level identification key to soldier major for all species of *Schedorhinotermes* was given by Maiti (2006), while Roonwal and Chottani (1989) keyed both the soldier major as well as soldier minor of the species, then known from the Indian region.

Schedorhinotermes has most of its species distributed in Oriental Region (Krishna *et al.*, 2013). In India, 6 species are known from Andaman and Nicobar islands only, and are absent in India mainland. However two species, *S. translucens* (Haviland) and *S. malaccensis* (Holmgren) are reported from Meghalaya (Maiti, 2006). All species seen in

the Indian region, except *S. longirostris* (Brauer), *S. malaccensis* (Holmgren), and *S. translucens* (Haviland) are exclusively Oriental in distribution, the above 3 species are reported from the neighbouring Papua Region also.

Two species, *S. eleanorae* Roonwal and Bose and *S. tiwarii* Roonwal and Thakur are endemic to Andamans, while *S. nancowriensis* Maiti and Chakraborty is known only from Nicobar. The remaining 5 species *S. longirostris* (Brauer), *S. makassarensis* Kemner, *S. malaccensis* (Holmgren), *S. medioobscurus* (Holmgren), *S. translucens* (Haviland) have their strong presence in Southeast Asia, falling under Sunda Region biodiversity hotspot (Krishna *et al.*, 2013).

According to the key to the soldier major, *S. makassarensis* comes near to *S. medioobscurus* in couplet No. 6 (Maiti, 2006). *S. makassarensis* is distinguished from all the other species, in having angularly rounded lateral margins at the widest width of head (Maiti, 2006), while *S. medioobscurus* is having faintly rounded lateral margin of head. In the key to minor soldiers of the genus, *S. makassarensis* is close to three species: *S. tiwari*, *S. translucens* and *S. medioobscurus*. *S. tiwari* has comparatively larger head length (0.90-1.07 mm) than *S. makassarensis* (0.80-0.92 mm). *S. translucens* is different in having much higher head mandibular index (0.82) than that of *S. makassarensis* (0.58) and head of *S. makassarensis* is distinctly wider (0.77-0.81 mm) than the head of *S. medioobscurus* (0.66-0.72 mm).

Key to the species of Genus

Schedorhinotermes in India

Soldier Major (except *S. eleanorae* as description is unknown)

1. Head larger with narrowed anterior end (head length: 2.28-2.34 mm; head width: 2.14-2.34 mm).....***S. malaccensis* (Holmgren)**
- Head comparatively smaller (head length: 1.34-2.08 mm; head width: 1.33-1.84 mm).....2
2. Head subsquarish; mandibles longer (0.84-1.12 mm).....3
- Head oval, mandibles shorter (0.80 mm)....
.....***S. longirostris* (Brauer)**
3. Mandibles somewhat thinner and less hooked at tip; 3rd segment of antenna

slightly longer than 2nd***S. tiwarii* Roonwal and Thakur**

- Mandibles robust and strongly hooked at tip; 3rd segment of antenna much longer (almost 1.5 times) than 2nd/4th4
- 4. Postmentum broader in width (minimum width of postmentum 0.26-0.28 mm; maximum width of postmentum 0.56-0.63 mm).....***S. nancowriensis* Maiti and Chakraborty**
- Postmentum narrower in width (minimum width of postmentum 0.23-0.33 mm; maximum width of postmentum less than 0.46 mm).....5
- 5. Head in profile not so depressed behind antennae; postmentum comparatively broader at waist (postmentum waist 0.28-0.33 mm).....***S. translucens* (Haviland)**
- Head in profile depressed behind antennae; postmentum comparatively narrower at waist (postmentum waist 0.26-0.28 mm)...6
- 6. Pronotum smaller; maximum length of pronotum < 0.55 mm (0.49-0.55 mm); width of pronotum 0.67-0.72 mm; pronotum head index (pronotum width/head width) 0.55. Lateral margin of head angularly rounded...***S. makassarensis* Kemner**
- Pronotum larger; maximum length of pronotum > 0.55 mm (0.55-0.60 mm); width of pronotum 0.85-0.95 mm; pronotum head index (pronotum width/head width) 0.59. Lateral margins of head faintly rounded.....***S. medioobscurus* (Holmgren)**

Soldier Minor

1. Head larger (head length to base of mandible 1.04-1.26 mm; head width 0.91-1.02 mm).....***S. malaccensis* (Holmgren)**
- Head comparatively smaller (head length to base of mandible 0.73-1.07 mm; head width 0.66-0.98 mm).....2
2. Head hexagonal, maximum width of postmentum 0.34-0.37 mm.....
.....***S. nancowriensis* Maiti and Chakraborty**
- Head oval, maximum width of postmentum 0.27-0.34 mm.....3
3. Head oval, sides not sharply bulging out behind antenna.....4
- Head broadly oval, sides sharply bulging out behind antenna.....5
4. Postmentum minimum width < 0.20 mm. antenna with 14 segments....***S. eleanorae* Roonwal and Bose**

- Postmentum minimum width > 0.20 mm (0.23-0.25 mm); antenna with 15 to 16 segments.....*S. longirostris* (Brauer)
- 5. Mandible length < 0.50 mm; head mandibular index (mandible length/head length) 0.58.....*S. makassarensis* Kemner
- Mandible length > 0.50 mm; head mandibular index (mandible length/head length) 0.59-0.82.....6
- 6 Head mandibular index 0.82.....*S. translucens* (Haviland)
- Head mandibular index 0.59-0.69.....7
- 7. Head mandibular index 0.69.....*S. medioobscurus* (Holmgren)
- Head mandibular index 0.59-0.64.....*S. tiwarii* Roonwal and Thakur

Acknowledgements

The authors are grateful to the Director, Zoological Survey of India (ZSI), Kolkata for support and encouragement.

References

- Brauer, F. 1865. Funfter Bericht über die auf der Weltfahrt der Kais. Fregatte Novara gesammelten Neuropteren. Verhandlungen der Kaiserlich-Königlichen Zoologisch-Botanischen Gesellschaft in Wien 15: 975–978.
- Hagen, H.A. 1858. Monographie der Termiten. Linnaea Entomologica 12: i–iii + 4–342 + 459 + 3 pls.
- Haviland, G.D. 1898. Observations on termites; with descriptions of new species. Journal of the Linnean Society of London, Zoology 26(169): 358–442 + 4 pls.
- Holmgren, N. 1911. Termitenstudien. 2. Systematik der Termiten. Die Familien Mastotermitidae, Protermitidae und Mesotermitidae. Kungliga Svenska Vetenskaps-Akademiens Handlingar 46(6): 1–86 + 6 pls.
- Holmgren, N. 1913. Termitenstudien. 4. Versuch einer systematischen Monographie der Termiten der Orientalischen Region. Kungliga Svenska Vetenskaps-Akademiens Handlingar 50(2): 1–276 + 8 pls.
- Holmgren, N. 1914. Wissenschaftliche Ergebnisse einer Forschungsreise nach Ostindien, ausgeführt im Auftrage der Kgl. Preuss. Akademie der Wissenschaften zu Berlin von H. v. Buttel-Reepen. III. Termiten aus Sumatra,

- Java, Malacca und Ceylon. Gesammelt von Herrn Prof. Dr. v. Buttel-Reepen in den Jahren 1911–1912. Zoologische Jahrbucher, Abteilung für Systematik, Geographie und Biologie der Tiere 36(2–3): 229–290.
- Hill, G.F. 1942. Termites (Isoptera) from the Australian Region. Melbourne: Council for Scientific and Industrial Research, 479 pp. + 24 pls.
- Krishna, K., Grimaldi, D.A., Krishna, V. and Engel, M.S. 2013. Treatise on the Isoptera of the World. Bulletin American Museum of Natural History, No. 377 (<http://digitallibrary.amnh.org/dspace/handle/2246/6430>).
- Kemner, N.A. 1934. Systematische und biologische Studien über die Termiten Javas und Celebes. Kungliga Svenska Vetenskaps-Akademiens Handlingar 3(13(4): 1–241 + 22 pls.
- Maiti, P.K. 2006. A taxonomic monograph on the world species of termites of the family Rhinotermitidae (Isoptera: Insecta). Memoirs of the Zoological Survey of India 20(4): 1–272.
- Noirot, C. 2000. Formation of Castes in the Higher Termites. In: Biology of Termites. Vol. 1. New York: Academic Press, 311–350pp.
- Oshima, M. 1914. Notes on a collection of termites from the East Indian Archipelago. Annotationes Zoologicae Japonenses 8: 553–585.
- Potter, M.F. 1997. Termites. In: Mallis Handbook of Pest control, 8th Ed., Cleveland, Ohio: Mallis Hand book and Technical Training Company, 63–68pp.
- Pearce, M.J. 1997. Termites: Biology and Pest Management. New York: CABI Publishing, 86–92pp.
- Roonwal, M.L. and Chhotani, O.B. 1989. The fauna of India and adjacent countries. Isoptera (termites). (Introduction and families Termopsidae, Hodotermitidae, Kalotermitidae, Rhinotermitidae, Stylotermitidae and Indotermitidae). Vol. 1. Calcutta: Zoological Survey of India, [8] + viii + 672 pp.
- Sengupta, R., Basak, J., Rajmohana, K. and Baraik, B. 2018. Insecta: Isoptera (Blattodea) in Faunal Diversity of Biogeographic Zones: Islands of India. Kolkata: Zoological Survey of India, 1–523.

- Silvestri, F. 1909. Isoptera. *In*: W. Michaelsen, and R. Hartmeyer, (eds.), Die Fauna Sudwest-Australiens. Ergebnisseder Hamburger sudwest-australischen Forschungsreise 1905. Vol. 2, Part 17: 279–314.
- Snyder, T.E. 1949. Catalog of termites (Isoptera) of the world. Smithsonian Miscellaneous Collections, 112(3953): 1–490.
- Su, N.Y. and Scheffrahn, R.H. 1990. Economically important Termites in the United State and their Control. *Sociobiology* 17: 77–94.
- Su, N.Y. and Scheffrahn, R.H. 1998. A Review of Subterranean Termites Control Practices and Prospects for Integrated Pest Management. *Integrated Pest Management Review* 3: 1 –13.

A new species of *Protanilla* Taylor 1990 (Hymenoptera: Formicidae: Leptanillinae) from India

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Abstract

Protanilla flamma sp. n. from Goa, India is described, which is the thirteenth species in the genus *Protanilla* and the second record of this genus from the country. The new species morphologically appears close to *P. lini* Terayama, 2009 in terms of mandibular teeth count and the structure of petiolar and post-petiolar nodes. However, it can be very easily differentiated based on the short antennal scape which does not exceed the posterior margin of the head.

Keywords: *Leptanillinae, Protanilla, new species, key to species, India, Goa.*

Received: 5 February 2020; Revised: 5 July 2020; Online: 15 July 2020

Introduction

The genus *Protanilla* Taylor, 1990 belongs to the subfamily Leptanillinae which recent studies have favourably considered as the sister group to all known extant ant species of the world (Ward, 2014). Currently represented by 12 valid species (Dias *et al.*, 2019), this genus is distributed across the Indo-Malayan, Australasian and southern-Paleotropical regions of the world (Bolton, 2020). This genus is typically characterised by its narrow, elongate, downcurved and triangular mandibles, with inner surface armed with numerous blunt and elongate peg-like to pencil-like teeth (Bolton, 1990). Much of the natural history knowledge of this genus remains unclear, except for information of two species from Taiwan (Hsu *et al.*, 2017), which is primarily due to their cryptic and subterranean life history making them a challenge to encounter while utilising conventional collection techniques (Man *et al.*, 2017).

Protanilla flamma sp. n. described here represents the second record of this genus from India (Bharti *et al.*, 2016) and the 13th valid species of this genus worldwide.

Materials and Methods

Two specimens were collected during field work in Netravali Wildlife Sanctuary at the foothills of the Western Ghats of Goa. The specimens were collected during the post-

monsoon season of 2016, when the top 4 cm thick leaf-litter and 2-3 cm of soil was disturbed to reveal the collected individuals within the soil. The area where the specimens were collected is situated at an elevation of 445 m above sea level with thick forest canopy, mostly dominated by moist-deciduous tree species. The forest floor was still wet from the just concluded monsoons and the temperature at the site on the time of collection was 33 °C. Two specimens of the new species were collected by hand and stored in 70% ethanol. Taxonomic analysis and measurements were recorded using a Leica 205 C stereomicroscope and are reported in millimeters. For acquiring digital images, a Leica MC 120 HD digital camera was used on the same microscope with an external stacking software Image J. Clarity of images were then enhanced using GNU Image Manipulation Program GIMP v 2.10.12. Standard measurements, indices, morphological terminologies, and description follow Bolton (1990) and Hsu *et al.* (2017).

TL The total outstretched length of the ant from the mandibular apex to the gastral apex.

HL Head length: The length of the head in full-face view, excluding the mandibles and measured in a straight line from the midpoint of the anterior

	clypeus margin to the midpoint of the posterior margin.
HW	Head width: The maximum width of the head behind eyes in full-face view.
CI	Cephalic index: $(HW \times 100) / HL$.
SL	Scape length: The maximum length of the antenna scape excluding basal condyle and neck.
SI	Scape index: $(SL \times 100) / HW$.
ML	Mandible length: The length of the mandible from the base to the apex.
PW	Pronotal width: Maximum pronotal width in dorsal view.
WL	Weber's length: The maximum diagonal length of mesosoma from the anterior most point of the pronotal slope (excluding neck) to the posteroventral margin of the propodeal lobe in profile view.
PNL	Petiolar node length: The maximum longitudinal length of the petiolar node, excluding its anterior and posterior peduncles in lateral view.
PNH	Petiolar node height: The maximum vertical height of the petiolar node from summit to lowermost part of subpetiolar process in lateral view.
PNW	Petiolar node width: The maximum width of the petiolar node in dorsal view.
PI	Petiolar Index: $(PNW \times 100) / PNL$.
PPNL	Postpetiolar node length: The maximum longitudinal length of the postpetiolar node, excluding its anterior and posterior peduncles in lateral view.
PPNH	Postpetiolar node height: The maximum vertical height of the postpetiolar node from summit to lowermost part of subpetiolar process in lateral view.
PPNW	Postpetiolar node width: The maximum width of the postpetiolar node in dorsal view.
PPI	Postpetiolar Index: $(PPNW \times 100) / PPNL$.

Relative values of morphological measurements were plotted to understand how the new species differs from other *Protanilla* species. Further, to visualise the clustering of species, an ordination technique for dimension reduction, the t-Distributed Stochastic Neighbour Embedding (t-SNE), was used (Maaten and Hinton, 2008). This analysis was

done using *tsne* package V 0.1-3 (Donaldson, 2016) and visualisation was performed using *ggplot2* V 3.3.1 (Wickham *et al.*, 2020). All these analysis were performed on R version 1.2.5019 (R Core Team, 2013) for Mac OS.

Acronyms of Depositories

GKVK: Gandhi Krishi Vignana Kendra, Bengaluru.

IISc: Indian Institute of Science, Bengaluru.

Systematics

Protanilla flamma Baidya and Bagchi sp. n.
(Figs. 1a-c)

[urn:lsid:zoobank.org:act:5CC9B108-6D0F-41F3-9003-33FB174EA843](https://zoobank.org/urn:lsid:zoobank.org:act:5CC9B108-6D0F-41F3-9003-33FB174EA843)

Type Material

Holotype worker: India, Goa, South Goa District, Netravali Wildlife Sanctuary, 15.599° N, 74.240° E, 445m asl, hand collected in moist deciduous forest, 25.ix.2016, Pronoy Baidya leg.

Paratype: One worker with same method of collection and data as holotype. Holotype deposited in IISc and Paratype will be deposited in GKVK.

Measurements (in mm)

Holotype: TL 2.5, HL 0.428, HW 0.355, CI 82.944, SL 0.323, SI 90.986, ML 0.249, PW 0.227, WL 0.724, PNL 0.199, PNH 0.288, PNW 0.218, PI 109.548, PPNL 0.179, PPNH 0.279, PPNW 0.221, PPI 123.464.

Paratype: TL 2.45, HL 0.425, HW 0.350, CI 82.353, SL 0.300, SI 85.714, ML 0.230, PW 0.225, WL 0.70, PNL 0.190, PNH 0.285, PNW 0.213, PI 112.105, PPNL 0.174, PPNH 0.275, PPNW 0.217, PPI 124.713.

Description

Body uniformly bright yellow and shiny. In full face, head longer than broad, anteriorly narrow with evenly convex sides. Antero-lateral corners of head produced into prominent angles. Posterior margin of head gently concave. Eyes absent. Mandibles elongated, smooth and shiny, apically strongly down-curved, basal margin rounded and masticatory margin with ~10 peg like teeth and a longitudinal groove runs along the dorsolateral margin of the mandible. Clypeus in full face is trapezoidal with depressed longitudinal central line, anterior margin



Figure 1. *Protanilla flamma* sp. n., holotype worker: **a.** Full-face view; **b.** Body in dorsal view; **c.** Body in profile view.

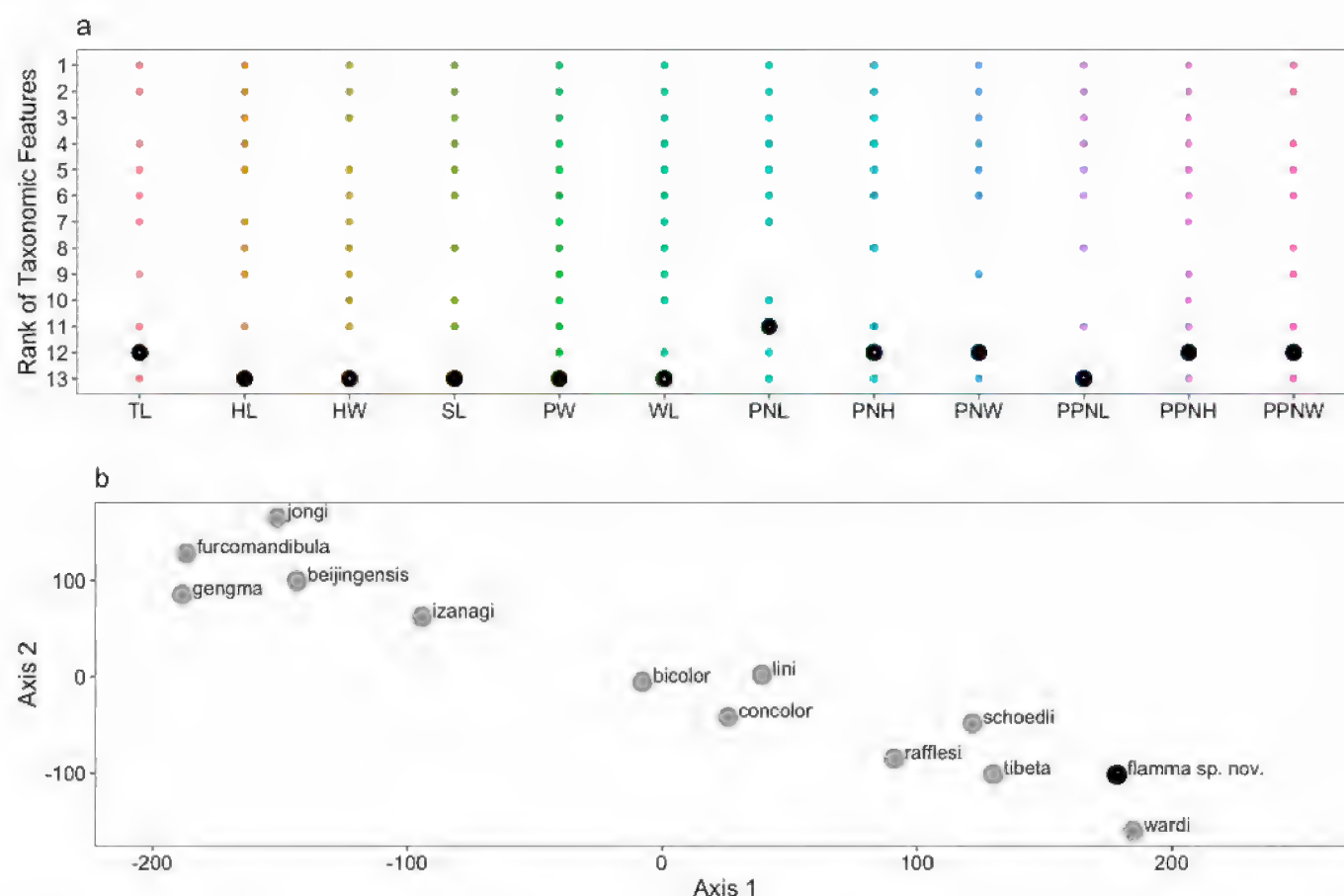


Figure 2. Morphometric comparison of *Protanilla flamma* sp. n. **a.** Relative morphological measurements of 13 species in the genus *Protanilla* ranked from 1(largest) to 13 (smallest), with *P. flamma* sp. n. represented by black dots. **b.** t-SNE ordination of morphometric data for *Protanilla flamma* sp. n. and other congeneric species.

slightly concave. Antenna 12 segmented; scape short not exceeding the posterior margin of the head; segments 2-4 wider than long; segments 5-10 nearly as long as broad; terminal segment almost twice as long than broad.

In profile view, dorsum of pronotum gently convex, and approximately twice the size of mesonotum. Promesonotal suture distinct and slightly depressed. Dorsum of mesonotum almost straight and sloping downwards. Metanotal groove strongly notched. Dorsum of propodeum slopes posteriorly, postereodorsal corner rounded. Petiolar node narrows slightly upwards; anterior and posterior faces both straight and dorsum slightly convex. Subpetiolar process reduced. Post-petiolar node straight with dorsum slightly convex; ventral face strongly inclined forward and anteroventral corner blunt; broadly attached to abdominal segment with free posterior face above the articulation with segment IV. Gaster oval in shape and more constricted anteriorly; length of Tergite I more than half the length of gaster. Sting well developed.

In dorsal view, mesonotum constricted, and 1.5 times smaller in width than the pronotum. Petiolar and post-petiolar nodes as long as broad with convex sides and of comparable size. Anterior margin of abdominal segment IV deeply concave to accept the laterally compressed post-petiole.

Dorsum of head, mesosoma, petiolar node, post-petiolar node and gaster, with short pubescence. Entire body covered sparsely with suberect hairs.

Etymology

The name of the new species is inspired by Prof. Vaibhav Chindarkar. In Sanskrit, “vaibhav” means eminence – like the glow of a flame in the dark. Incidentally, this species is also yellowish-orange in colour (Fig. 1). Hence, “flamma”.

Differential Diagnosis

In terms of the number of mandibular teeth and the structure of petiolar and post-petiolar nodes, *P. flamma* sp. n. appears morphologically close to *P. lini* Terayama, 2009. However, the new species can be very easily differentiated based on the short antennal scape which does not exceed the posterior margin of the head (SI 91.0 in

comparison to *P. lini* where the scape exceeds the posterior margin of the head (SI 104.2).

In terms of individual morphometric measurements (TL, HL, HW, SL, PW, WL, PNL, PNH, PNW, PPNL, PPNH and PPNW) the new species has generally smaller features than the other congeneric species (Fig. 2a). In two-dimensional ordination space, the new species is closer to *P. wardi* Bharti & Akbar, 2015, described from Kerala, India than the other *Protonilla* species (Fig. 2b).

Key to known valid species of *Protonilla* of the world based on the worker caste

The new species, keys out to *P. lini* based on the key provided by Hsu *et al.* (2017), however differs based on a shorter antennal scape leading us to introduce a new couplet #9 and moving the last couplet to #10 as below. Therefore couplet #1 through #8 are identical to the existing key for *Protonilla* as provided by Hsu *et al.* (2017).

1. Mandibles with a large convex dorsal lamella and a large longitudinal groove on outer surface.....***P. izanagi* Terayama (Japan)**
 - Mandibles thin, long and narrowly triangular, without a dorsal lamella; with or without a groove on outer surface.....**2**
2. Lateral or ventral margin of mandibles with 1–2 denticles. Postpetiole broadly attached to abdominal segment IV..... **3**
 - Lateral and ventral margin of mandibles smooth, without denticle. Postpetiole narrowly attached to abdominal segment IV.....**4**
3. Ventral faces of mandibles with only one inconspicuous denticle. Anterior margin of abdominal segment IV in dorsal view slightly concave. Side of abdominal segment IV with a deep and narrow notch between the tergite and sternite at the anterior margin. In profile view, postpetiolar sternite nearly straight, and anterior corner forming a right angle.....
.....***P. jongi* Hsu *et al.* (Taiwan)**
 - Lateroventral margins of mandibles armed with 2 distinct teeth (one long and one short). Anterior margin of abdominal segment IV in dorsal view deeply concave. Side of abdominal segment IV without a deep and narrow notch between the tergite and sternite at the anterior margin. In

- profile view, postpetiolar sternite deeply concave.....*P. furcomandibula* Xu (China: Yunnan)
4. In full face view, anterior margin of clypeus strongly concave. In dorsal view, petiole distinctly longer than broad. Body bicolored, the middle portion black, the rest brownish yellow.....5
 - In full-face view, anterior margin of clypeus straight to weakly concave. In dorsal view, petiole as broad as long or broader than long. Body concolorous, uniformly yellowish brown or reddish brown.....6
 5. In full-face view, anterior 1/3 of the head distinctly narrowed. In profile view, anterior and dorsal faces of petiolar node some-what differentiated, meeting at a broadly rounded angle. Head brownish yellow. Body small (HW 0.42–0.45 mm in types).....*P. bicolor* Xu (China: Yunnan)
 - In full face view, anterior half of head distinctly narrowed. In profile view, petiolar node evenly rounded, with no differentiation of anterior and dorsal faces. Head light black to blackish brown. Body large (HW 0.60–0.65 mm in types).....*P. gengma* Xu (China: Yunnan)
 6. In profile view, anterior face of petiole distinctly concave, anterodorsal corner protruding.....7
 - In profile view, anterior face of petiole straight, sloped or slightly convex.....8
 7. Petiole distinctly broader than long, slightly widened posteriorly. In profile view, top half of postpetiole slightly inclined anteriorly and roughly round.....*P. rafflesi* Taylor (Singapore and Malaysia)
 - Petiole nearly square in dorsal view, as broad as long, weakly narrowed posteriorly. In profile view, top half of postpetioleroughly rectangular, with straight anterior and posterior face.....*P. wardi* Bharti & Akbar (India: Kerala)
 8. Top half of postpetiole not inclined forward, posterodorsal corner angled. In dorsal view, both petiole and postpetiole round, as long as broad.....9
 - Top half of postpetiole strongly inclined forward. In dorsal view, at least petiole or postpetiole compressed anteroposteriorly, broader than long.....10
 9. Scape exceeds the posterior margin of the head (SI 104.167).....*P. lini* Terayama (Taiwan)
 - Scape does not extend beyond the posterior margin of the head (SI 90.986).. *P. flamma* sp. n. (India: Goa)
 10. In full face view, anterolateral corners of head prominent and tooth-like. In profile view, petiole relatively thick and roughly trapezoidal, dorsal face long, approximately as long as anterior face.....*P. tibeta* Xu (China: Tibet)
 - In full face view, anterolateral corners of head smooth and without prominent tooth-like structures. In profile view, petiole relatively thin and roughly triangular, dorsal face short, approximately half the length of anterior face.....*P. concolor* Xu (China: Yunnan)

Acknowledgements

The authors would like to thank DBT-IISc Partnership, DST-FIST, MOEF-CC and fellowships from MHRD through IISc. We thank Goa Forest Department and PCCF's office for research permits. Centre for Environment Education- Goa State Office and Mr. Sujeet Dongre for logistical aid for fieldwork, Dr. Thresiamma Varghese for assistance at IISc Museum, Prof. Himender Bharti for constructive comments, guidance and the reviewers, Dr. Francisco Hita Garcia, Dr. David E. M. General and Dr. Cong Liu for their critical evaluation and modifications.

References

- Bharti, H. and Akbar, S.A. 2015. First record of genus *Protanilla* (Hymenoptera: Formicidae: Leptanillinae) from India with description of a new species. *Journal of Asia-Pacific Entomology* 18: 573–576. <https://doi.org/10.1016/j.aspen.2015.04.008>
- Bharti, H., Guénard, B., Bharti, M. and Economo, E.P. 2016. An updated checklist of the ants of India with their specific distributions in Indian states (Hymenoptera, Formicidae). *ZooKeys* 551: 1-83. <https://doi.org/10.3897/zookeys.551.6767>
- Bolton, B. 2020. An online catalog of the ants of the world. < <https://www.antcat.org>>, accessed on 29 May 2020.
- Bolton, B. 1990. The higher classification of the ant subfamily Leptanillinae

- (Hymenoptera: Formicidae). *Systematic Entomology* 15: 267–282. <https://doi.org/10.1111/j.1365-3113.1990.tb00063.x>
- Dias, R.K.S., Yamane, S., Akbar, S.A., Peiris, H.A.W.S. and Wachkoo, A.A. 2019. Discovery of the worker caste of *Protanilla schoedli* Baroni Urbani & De Andrade (Formicidae: Leptanillinae) in Sri Lanka. *Oriental Insects* 53: 160–166. <https://doi.org/10.1080/00305316.2018.1476273>
- Donaldson, J. 2016. tsne: T-Distributed Stochastic Neighbor Embedding for R (t-SNE). <<https://github.com/jdonaldson/rtsne/>>, accessed on 29 May 2020.
- Hsu, P.-W., Hsu, F.-C., Hsiao, Y. and Lin, C.-C. 2017. Taxonomic notes on the genus *Protanilla* (Hymenoptera: Formicidae: Leptanillinae) from Taiwan. *Zootaxa* 4268: 117–130. <https://doi.org/10.11646/zootaxa.4268:1-7>
- Maaten, L. van der. and Hinton, G. 2008. Visualizing Data using t-SNE. *Journal of Machine Learning Research* 9: 2579–2605.
- Man, P., Ran, H., Chen, Z. and Xu, Z. 2017. The northern-most record of Leptanillinae in China with description of *Protanilla beijingensis* sp. nov. (Hymenoptera: Formicidae). *Asian Myrmecology* 9: 1–12. <https://doi.org/10.20362/am.009008>
- R Core Team. 2013. R: A language and environment for statistical computing. <<https://cran.r-project.org>>, accessed on 29 May 2020.
- Ward, P.S. 2014. The Phylogeny and Evolution of Ants. *Annual Review of Ecology Evolution and Systematics* 45: 23–43. <https://doi.org/10.1146/annurev-ecolsys-120213-091824>
- Wickham, H., Chang, W., Henry, L., Pedersen, T.L., Takahashi, K., Wilke, C., Woo, K., Yutani, H. and Dunnington, D. 2020. ggplot2: Create Elegant Data Visualisations Using the Grammar of Graphics. R package version 3.3.1. <<http://ggplot2.tidyverse.org>, <https://github.com/tidyverse/ggplot2>>, accessed on 29 May 2020.

Descriptions of two new species of *Macroteleia* Westwood (Hymenoptera: Scelionidae) from India

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Abstract

This paper describes two new species of *Macroteleia* Westwood, viz., *M. kairalii* sp. n. and *M. shyaama* sp. n. from India. A key to species of India, based on females is also provided.

Keywords: Hymenoptera, Platygasteridae, new species, Scelioninae.

Received: 1 January 2020; Revised: 30 August 2020; Online: 14 September 2020

Introduction

The genus *Macroteleia* (Platygastroidea: Scelionidae) was erected by Westwood (1835) based on type species *Macroteleia cleonymoides* Westwood. As per the available host data, members of this genus are egg-parasitoids of long-horned grasshoppers (Orthoptera: Tettigoniidae) (Chen *et al.*, 2013). Ashmead (1893) reared them from *Orchelimum glaberrimum* (Burmeister, 1838) (Orthoptera: Tettigoniidae), while Morgan (1901), Brues (1907), Cole (1931), Priesner (1951), Muesebeck (1977) and Kononova and Kozlov (2008) too reared them from orthopteran eggs.

With an elongate and robust habitus, *Macroteleia* is close to *Habroteleia* Kieffer and *Triteleia* Kieffer, though the absence of post marginal vein easily separates *Habroteleia*. *Macroteleia* can be differentiated from *Triteleia* by their laterally compressed sixth tergite in females; the same is dorsoventrally flattened and triangular in *Triteleia* females. In *Macroteleia* males, the apical tergite is apically emarginate or with a terminal single spine, while postero-lateral corners of male apical tergite is bispinose in *Triteleia* (Masner, 1976; Chen *et al.*, 2013).

The genus is represented by 133 valid species globally (Hymenoptera Online, 2020), of which only 8 species are reported from India (Mani and Sharma, 1982; Rajmohana, 2006). In this paper two new species *M. kairalii* sp. n. and *M. shyaama* sp. n. are described. A key to Indian species of

Macroteleia Westwood, based on females is also provided.

Materials and Methods

The present study is based on specimens collected through Malaise traps, Yellow pan traps, and Sweep net. Specimens were studied and imaged under Leica M 205A stereomicroscope, with Leica DFC 500 camera. Images were processed using extended focus montage LAS software. The holotypes and other material examined are deposited at Western Ghat Regional Centre, Zoological Survey of India, Kozhikode, Kerala (ZSI, WGRC). Terminology followed is based on Miko *et al.*, 2007.

Abbreviations

A1-A12- Antennal segments; HL- Head length; HW- Head width; EH- Eye height; IOS- Inter orbital space; L- Length; *m*- Marginal vein; MW- Mesosoma width; ML- Mesosoma length; OOL- Ocello-ocular length; OD- Ocellar diameter of median ocellus; *pm*- Post marginal vein; POL- Posterior ocellar length; LOL- Lateral ocellar length; *stg*- Stigmal vein; T1-T2- Tergites of metasoma; S2-S6- Sternites of metasoma; W- Width.

Results

Key to the species of genus *Macroteleia* Westwood from India based on females

1. Propodeum divided into two separate triangular lobes.....2

- Propodeum continuous medially, not divided into two separate lobes.....4
- 2. Metascutellum triangular, strongly produced medially.....*M. lamba*
Saraswat and Sharma
- Metascutellum tongue- like.....3
- 3. Body black; gena coarsely punctate rugose; netrion punctate or rugulose punctate; metapleuron longitudinally striate dorsally, densely punctate ventrally..... *M. crawfordi* Kieffer
- Body yellowish brown to brown; gena densely punctate; netrion rugulose; metapleuron punctate.....*M. chandelii*
Mani and Sharma
- 4. T5 distinctly wider than long5
- T5 distinctly longer than wide.....6
- 5. Metascutellum tongue- like, not extending into space between propodeal lobes (not as broad as *M. crawfordi*); metasoma black.....*M. shyaama* sp. n.
- Metascutellum transverse, posterior margin slightly pointed medially; base of T1, T5 and T6 brown to black, rest of metasoma yellow or orange..... *M. indica*
Saraswat and Sharma
- 6. Mesosoma pale brown or yellowish orange.....7
- Mesosoma entirely black.....8
- 7. Head black; metascutellum transverse, posterior margin pointed medially; T1 black, T2 mixed brown and black.....
.....*M. dolichopa* Sharma
- Head brown; metascutellum transverse, posterior margin toothed or pointed with medial tooth very long and broad; T1 and T2 pale brown.....*M. kairalii* sp. n.
- 8. Metasoma mixed brown and black; medial frons punctate rugulose ventrally, irregularly smooth dorsally; A1 and A2 yellowish brown, A3- A6 pale brown, rest of antenna black.....*M. striativentris*
Crawford
- Metasoma black; medial frons obliquely strigose ventrally and irregularly smooth dorsally; A1- A6 yellowish brown, rest of antenna black.....*M. livingstoni*
Saraswat

***Macroteleia kairalii* Abhilash and
Rajmohana sp. n.**

(Figs: 1-8)

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Description: Holotype Female. Length= 6.3mm.

Colour: Head and mesosoma yellow to orange or pale brown; metasoma yellow to orange or pale brown except 3/4th of T6 and rest of segments dark brown to black; mandible yellow or orange with teeth brown or black; legs yellow to pale brown throughout; A1 yellow to pale brown, A2-A6 pale or dark brown, rest of antenna dark brown to black; wings hyaline.

Head: In dorsal view transverse, 1.63x as wide as long, slightly wider than mesosoma; central keel absent; minimal distance of IOS in front of median ocellus less than EH (29: 43) in front view; frons with setigerous punctae, medially smooth and impunctate; frons below median ocellus and also vertex with dense non contiguous setigerous punctae; lower frons with rugulae converging towards antennal toruli. OOL very short, 0.13x OD; POL 1.25x LOL; ocellar triangle smooth with scattered punctures; gena with setigerous punctae; occipital carina incomplete medially; A3 0.91x as long as A2.

Mesosoma: In dorsal view 1.52x as long as wide, hairy; netrion hairy, finely punctate; middle lobe of mesoscutum evenly punctate, punctae larger posteriorly than in front; lateral lobes of mesoscutum smooth with a row of punctae; notauli narrow, foveate; mesoscutellum finely punctate throughout, carinate and with foveolate border posteriorly; metascutellum transverse, carinate and foveolate; metascutellum apically toothed, with a pair of small submedial projections (Fig.7); propodeum continuous medially (Fig.7) not divided into two separate lobes, posterior margin notched medially, each side with irregular longitudinal carinae; medially covered by dense, decumbent, hairs; both cervical and dorsal pronotal area with dense setigerous punctae; lateral pronotal area smooth anteriorly and posteriorly punctate rugulose; upper mesepisternum with a row of robust longitudinal carinae below subalar pit; lower mesepisternum longitudinally punctate rugulose and setose; mesopleural depression smooth; metapleuron longitudinally striate at its anterior and posterior, but medially with punctate to punctate rugose sculptures, sparsely hairy; hind femur swollen medially; spines absent on outer surface of hind tibia; forewing L: W= (350: 90); forewing apex extending as far as posterior margin of T4 to

middle of T5; m 0.52x length of pm ; pm 3.6x longer than stg ; $pm: stg: m = 54: 15: 28$.

Metasoma: In dorsal view, 2.79x longer than head and mesosoma combined, setose; posterior margin of transverse sulcus on T2 slightly convex; sublateral tergal carinae distinct on T1- T4; T1 longitudinally striate medially, with scattered punctures in interstices anteriorly, rugulose laterally; T2- T4 longitudinally striate with punctures scattered in interstices medially and punctate rugulose laterally; T5 densely longitudinally striate throughout with delicate punctures in interstices; T6 finely punctate dorsally, densely longitudinally striate laterally with scattered punctures in interstices; length of T3 0.91x length of T6; T5 distinctly longer than wide (1.5x); relative L: W proportion of metasomal tergites T1- T6 being (66: 44); (78: 54); (88: 57); (82: 55) (60: 40); (97: 22); S2- S4 longitudinally striate, with punctures in interstices; S5- S6 densely longitudinally striate, with fine punctures in interstices; distinct longitudinal median carina present on S2- S5.

Male: Unknown

Host: Unknown

Diagnosis: *M. kairalii* sp. n. is similar to *M. indica* Saraswat and Sharma, *M. flava* Chen, Johnson, Masner, Xu, *M. rufa* Szelényi and *M. chandelii* Sharma in body shape, colour and size. In *M. kairalii* sp. n., T3 is not as long as T6 (Length of T3 1.11–1.39x length of T6 in *M. indica*) and T5 distinctly longer than wide (in *M. indica* T5 distinctly wider than long).

In *M. kairalii* sp. n., sublateral tergal carinae distinct on T1- T4 (in *M. flava* sublateral tergal carinae distinct on T1- T3) and metapleuron not fully striate, but medially punctate rugulose (in *M. flava*, metapleuron longitudinally striate throughout) and fore wing apex extending as far as posterior margin of T4 to middle of T5 (In *M. flava* fore wing apex not reaching T5).

Metascutellum is distinctly transverse in *M. kairalii* sp. n. (triangular in *M. rufa*, tongue-like in *M. chandelii*), and propodeum is continuous medially, not divided into two separated lobes (divided into two subtriangular lobes in *M. rufa* and *M. chandelii*).

In *M. dolichopa*, though propodeum is continuous medially, it is a much larger species, with head black and metapleuron

longitudinally striate anteriorly and punctate rugulose ventrally.

Etymology: The species name is derived from Malayalam word ‘kairalii’ = belonging to Kerala, the South Indian state from where the species was collected.

Material examined: Holotype ♀, INDIA, Kerala, Tholpetty (11.86957E and 76.07291N), Wayanad District, 10.x.2013, Coll. Abhilash Peter, (ZSI/WGRS/IR.INV. 5793).

***Macroteleia shyaama* Abhilash and Rajmohana sp. n.**

(Figs: 9-16)

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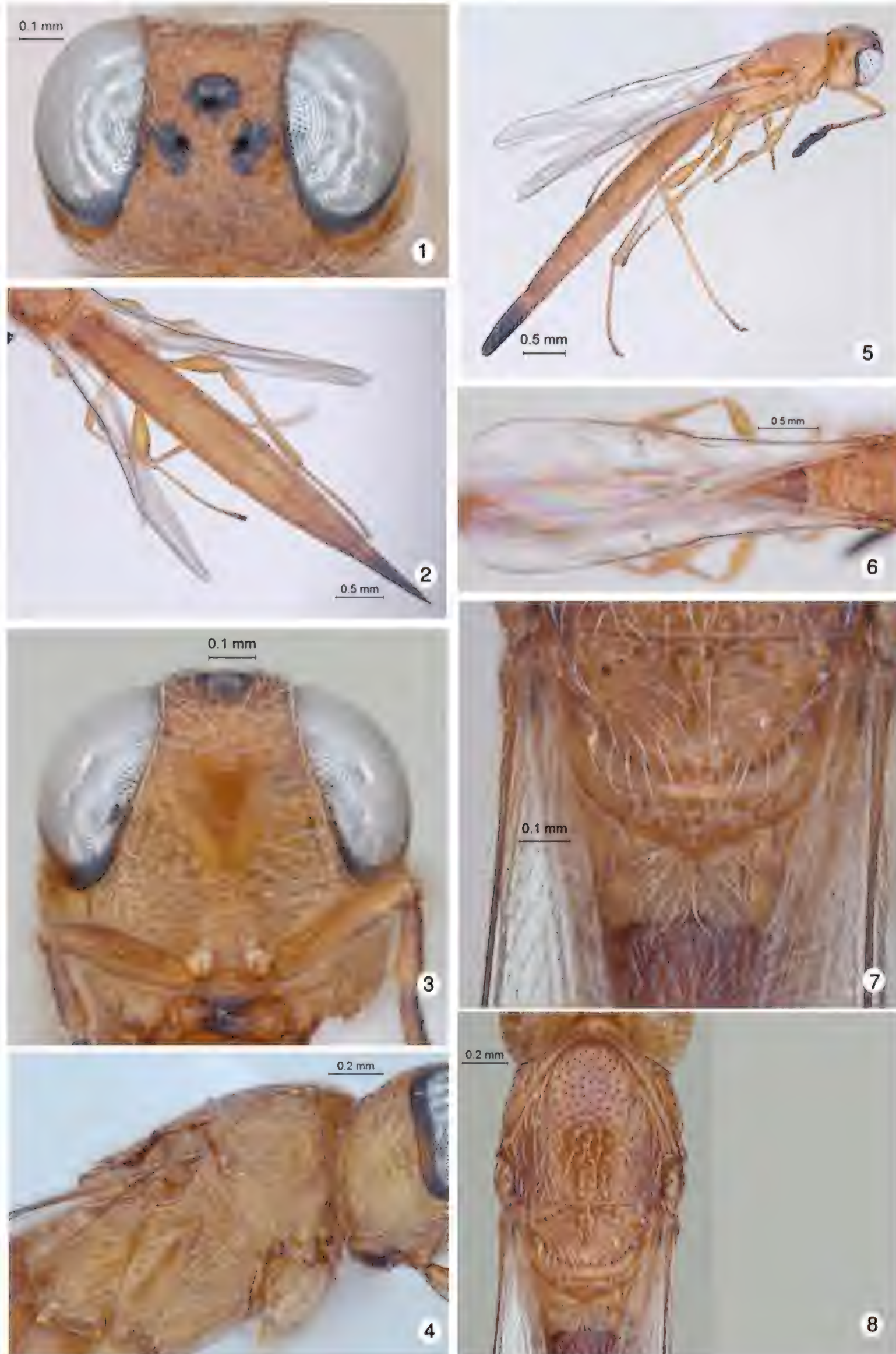
Description: Holotype Female. Length= 4.08mm.

Colour: Head and mesosoma orange yellow, except as follows: head dorsally, medial lobe of mesoscutum and posterior margin of propodeum dark brown to black; metasoma black; mandible yellow or orange with teeth brown or black; legs yellow throughout; A1 yellow, A2- A6 pale or dark brown, rest of antenna dark brown to black; wings hyaline.

Head: In dorsal view transverse, 0.62x as wide as long, slightly wider than mesosoma; central keel weakly developed; IOS less than EH (31: 43) in front view; medial frons obliquely strigose ventrally, irregularly smooth dorsally; ventrolateral frons punctate rugose; frons below median ocellus punctate, not contiguous; ocellar triangle and gena punctate; OOL short, 0.14x diameter of lateral ocellus; POL 1.45x LOL; occipital carina discontinuous medially; A2 and A3 almost subequal.

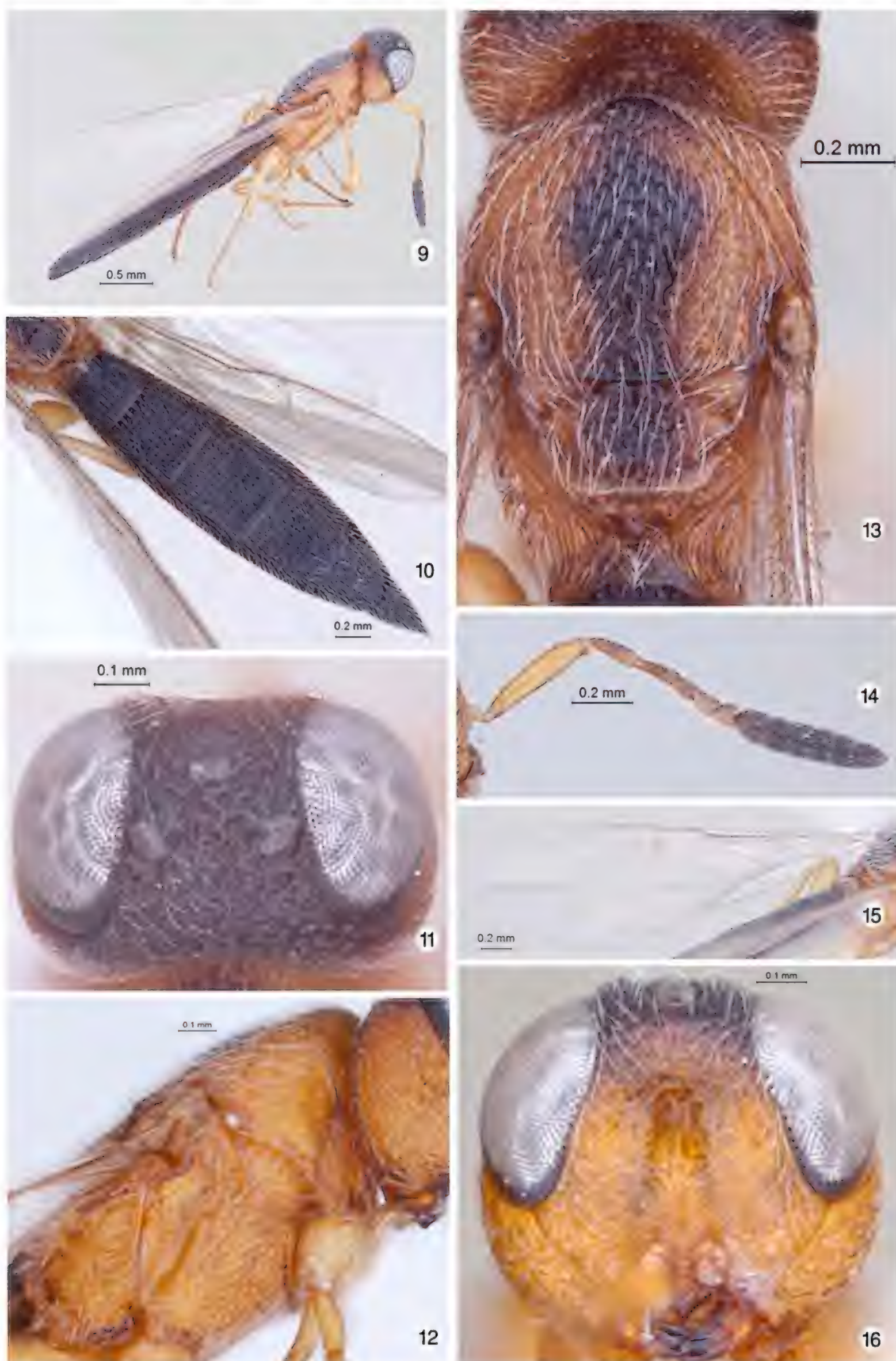
Mesosoma: In dorsal view 1.35x as long as wide, hairy; middle lobe of mesoscutum densely punctate anteriorly, punctate rugose to punctate reticulate posteriorly; lateral lobes of mesoscutum coarsely punctate throughout; notauli distinctly foveolate, foveolae contiguous; mesoscutellum punctate throughout, carinate and foveolate posteriorly; metascutellum tongue-like (not broad as in *M. crawfordi*), not extending into space between propodeal lobes, carinate and foveolate; propodeum continuous, medially not divided

PLATE 1



Figures 1-8: *Macroteleia kairalii* sp. n. Holotype (Female): 1. Head- dorsal; 2. Metasoma; 3. Head- front view; 4. Mesopleura; 5. Body profile; 6. Forewing venation; 7. Metascutellar plate; 8. Mesosoma.

PLATE 2



Figures 9-16: *Macroteleia shyaama* sp. n. Holotype (Female): **9.** Body profile; **10.** Metasoma; **11.** Head- dorsal; **12.** Mesopleura; **13.** Mesosoma; **14.** Antenna; **15.** Forewing venation; **16.** Head- front view.

into two separate subtriangular lobes, posterior margin narrowly notched medially, each side with irregular longitudinal carinae, covered medially by dense, decumbent, hairs; cervical and dorsal pronotal area densely punctate; lateral pronotal area smooth, anteriorly punctate and rugulose posteriorly; netrion hairy, punctate rugulose; upper mesepisternum with a row of weak longitudinal carinae below subalar pit; lower mesepisternum punctate rugulose; mesopleural depression smooth; metapleuron longitudinally striate throughout, not densely hairy; hind femur swollen; spines absent on outer surface of hind tibia; forewing L:W= (265: 79); forewing apex extending from as far as posterior margin of T5 to middle of T6; *m* 0.46x length of *pm*; *pm* 3.29x longer than *stg*; *pm*: *stg*: *m* = 46: 14: 21.

Metasoma: In dorsal view, 1.8x longer than head and mesosoma combined, hairy; posterior margin of transverse sulcus on T2 convex; sublateral tergal carinae distinct on T1- T3; T1 longitudinally striate medially, with scattered punctures in interstices anteriorly, rugulose laterally; T2- T4 densely longitudinally striate with punctures scattered in interstices medially and punctate rugulose laterally; T5 densely finely longitudinally striate throughout with delicate punctures in interstices; T6 finely punctate throughout; length of T3 1.42x length of T6; T5 distinctly wider than long (1.24x); relative L: W proportion of metasomal tergites T1 to T6 being (39: 44); (46: 56); (51: 60); (47: 57) (34: 42); (36: 21); S2- S4 longitudinally striate, with punctures in interstices; S5- S6 longitudinally striate, with fine punctures in interstices.

Male: Unknown.

Host: Unknown.

Etymology: The species name is derived from the Sanskrit word 'shyaama' = 'black', due to its black coloured metasoma, contrasting with the orange mesosoma.

Material examined: Holotype ♀, INDIA: Kerala, Cheriyanam (9.5197E; 77.2465N), Periyar Tiger Reserve, Idukki district, 05.iv.2013, Coll. Abhilash Peter, (ZSI/WGRS/IR.INV.5792); Paratype: 1 ♀, INDIA, Kerala, Perunthenaruvi, 9.414855E: 76.875401N, Ranni, Pathanamthitta district, 22.i.2014, Coll. Abhilash Peter, (ZSI/WGRS/IR.INV.5791).

Diagnosis: Though close to *M. indica* Saraswat and Sharma in having a medially continuous propodeum and T5 being wider than long, *M. shyaama* sp. n. can be readily separated from *M. indica* as follows (a) metasoma black in *M. shyaama* sp. n. (in *M. indica* base of T1, T5 and T6 brown to black, rest of metasoma yellow or orange), (b) forewing apex extending from as far as posterior margin of T5 to middle of T6 in *M. shyaama* sp. n. (in *M. indica* forewing apex extending from as far as posterior margin of T4 to posterior margin of T5), (c) metascutellum medially extended tongue-like in *M. shyaama* sp. n. (in *M. indica* metascutellum posterior margin slightly pointed medially). Further while *M. indica* has its head entirely yellow or orange, head in *M. shyaama* sp. n. is dorsally black and face, yellowish orange.

The Oriental species *M. semicircula* Chen, Johnson, Masner and Xu, can be well differentiated from *M. shyaama* sp. n. mainly by its propodeum, which is divided into two widely separated triangular lobes.

Acknowledgments

The authors are grateful to the Director, Zoological Survey of India (ZSI), Kolkata and the Officer-in-Charge, ZSI, Western Ghat Regional Centre, Kozhikode, Kerala, for providing facilities and encouragement.

References

- Ashmead, W.H. 1893. A monograph of the North American Proctotrypidae. Bulletin of the United States National Museum 45: 1-472. doi.10.5479/si.03629236.45.1
- Brues, C.T. 1907. Notes and descriptions of North American parasitic Hymenoptera. V. Bulletin of the Wisconsin Natural History Society 5: 150-161.
- Burmeister, H. 1838. Handbuch der Entomologie 2 2(I-VIII):736.
- Chen, H., Johnson, N.F., Masner, L. and Xu, Z.F. 2013. The genus *Macroteleia* Westwood (Hymenoptera, Platygasteridae s.l., Scelioninae) from China. ZooKeys 300: 1-98.
- Cole, A.C. 1931. Typha insects and their parasites. Entomological News 42: 35-39.
- Hymenoptera Online 2020. Accessed online on February 15th 2020, at <https://hol.osu.edu/search.html?limit=50&name=Macroteleia>

Descriptions of two new species of *Macroteleia* Westwood from India

- Kononova, S.V. and Kozlov, M.A. 2008. [Scelionids of the Palearctic (Hymenoptera, Scelionidae). Subfamily Scelioninae. Saint Petersburg: Tovarithchestvo Nauchnykh Izdaniy KMK, 489 pp.
- Mani, M.S. and Sharma, S.K. 1982. Proctotrupoidea (Hymenoptera) from India. A review. Oriental Insects 16: 135-258.
- Masner, L. 1976. Revisionary notes and keys to world genera of Scelionidae (Hymenoptera: Proctotrupoidea). Memoirs of the Entomological Society of Canada 97: 1-87.
- Mikó I., Vilhelmsen L., Johnson N.F., Masner L. and Péntzes Z. 2007. Skeletomusculature of Scelionidae (Hymenoptera: Platygastroidea): head and mesosoma. Zootaxa 1571: 1–78.
- Morgan, H.A. 1901. The differential grasshopper in the Mississippi Delta – other common species. Bulletin of the United States Department of Agriculture, Division of Entomology (New Series) 30: 7-33.
- Muesebeck, C.F.W. 1977. The parasitic wasps of the genus *Macroteleia* Westwood of the New World (Hymenoptera, Proctotrupoidea, Scelionidae). U.S. Department of Agriculture Technical Bulletin 1565: 1-57
- Priesner, H. 1951. New genera and species of Scelionidae(Hymenoptera,Proctotrupoidea) from Egypt. Bulletin de l’Institut Fouad I du Desert 1(2): 119-149
- Rajmohana, K. 2006. Studies on Proctotrupoidea and Platygastroidea (Hymenoptera: Insecta) of Kerala. Memoirs of the Zoological Survey of India 21(1): 1-153.
- Westwood, 1835. Characters of new genera and species of hymenopterous insects. Proceedings of the Zoological Society of London, 3: 51-72.

***Vombisidris freyae*, a new nocturnal arboreal ant species from the Philippines (Hymenoptera: Formicidae)**

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Abstract

A new species, *Vombisidris freyae* sp. n., collected by nocturnal sampling of low vegetation, is described from the Philippines. The rarity of *Vombisidris* is briefly discussed.

Keywords: *arboreal, Formicidae, new species, nocturnal, Vombisidris.*

Received: 1 May 2020; Revised: 27 August 2020; Online: 14 September 2020

Introduction

The genus *Vombisidris* Bolton, 1991 was erected to accommodate myrmicine ants possessing a couple of unique morphological characters: a) a subocular groove laterally on the head, except for *V. bilongrudi* (Taylor, 1989) which does not possess this groove; and b) mandibular dentition consisting of a large apical tooth, followed by two smaller teeth, a large diastema, and finally two more small teeth (Bolton, 1991). There are currently 17 species known in this genus, ranging throughout the Oriental and Indo-Australian bioregions (Bolton, 2020). The genus is poorly represented in collections and is considered rare (Bolton, 1991).

There are at least two species known from the Philippines although only one species has been formally described. Zettel and Sorger (2010) described *V. philippina* Zettel and Sorger, 2010, the first species known from the Philippines. In the same paper, they also described a dealate queen, that likely represents a different species, which they declined to name.

Vombisidris ants are considered to be arboreal or sub-arboreal but very little is known of their biology (Bolton, 1991; Xu and Yu, 2012).

This paper describes and proposes a name to one of the unidentified species in the study of General *et al.* (2020) and provides a better understanding of the nocturnal arboreal

ant diversity of the Philippines.

Materials and Methods

Measurements (in millimetres), arranged sequentially from anterior to posterior, and acronyms follow Zettel and Sorger (2010) to facilitate comparison with the species treated therein.

- HL** Head length, maximum length of head capsule, excluding mandibles, from anterior-most point of clypeal margin to posterior-most point of head capsule, measured in full face view.
- HW** Maximum head width, including eyes when they exceed the lateral margin of the head, measured in full face view.
- SL** Scape length, maximum length of scape, excluding basal neck and condyle, measured at the appropriate angle such that the scape is positioned perpendicularly to the viewer.
- EL** Maximum eye length, measured along the longest axis of eye.
- WL** Weber's Length, mesosomal length measured from anterior edge of the pronotum (excluding the collar) to posterior edge of propodeal lobe.
- PW** Maximum width of pronotum, measured in dorsal view.
- FL** Hind femur length, maximum length of hind femur.

Indices

- CI** Cephalic index: HW/HL x 100
SI Scape index: SL/HW x 100
EI Eye index: EL/HW x 100
FI Hind Femur Index: FL/HW x 100

Collection Abbreviations (mostly from Brandão, 2000)

- MCZC** Museum of Comparative Zoology, Harvard University, Cambridge, MA, USA.
PNM Philippine National Museum of Natural History, Manila, Philippines.
UPLB University of the Philippine Los Baños, Museum of Natural History Entomological Collection, Los Baños, Laguna, Philippines.

Specimens were examined and measured using a Leica S8 stereomicroscope with ocular micrometer. Images of the ant were created using a Leica MC120HD digital camera attached to the Leica S8 stereomicroscope. These images were stacked using Combine ZM. The stacked images were edited with Adobe Photoshop CS5.

Taxonomy

Key to the Philippine species of *Vombisidris*

1. Head and body dark brown; antennal scrobe indistinct; subocular groove sinuate; propodeal spiracle low, situated at the level of the propodeal spine.....*V. philippina* Zettel and Sorger
- Head and body golden yellow; antennal scrobe distinct but shallow; subocular groove straight; propodeal spiracle high on the side, situated higher than base of propodeal spine..... *V. freyae* sp. n.

Species Account

Vombisidris freyae General sp. n.
 (Figures 1-3)

[urn:lsid:zoobank.org:act:4AEE87E8-CABD-491D-8A1E-CB0BD0979ECB](https://zoobank.org/act:4AEE87E8-CABD-491D-8A1E-CB0BD0979ECB)

Holotype Measurements (mm), (two paratype specimens in parenthesis): HL 0.63 (0.69, 0.64); HW 0.56 (0.63, 0.60); SL 0.41 (0.46, 0.45); EL 0.16 (0.16, 0.15); WL 0.83 (0.94, 0.88); PW 0.43 (0.46, 0.45); FL 0.50 (0.55, 0.51); CI 90 (91, 94); SI 73 (74, 75); EI 29 (26, 25); FI 89 (88, 85).

Diagnosis: With typical *Vombisidris* dentition; subocular groove complete, almost straight; sparse, blunt erect setae on dorsum of head and body; body, except gaster, rugoreticulate; gaster largely smooth, but with short basigastral costulae; metanotal groove absent; body concolorous brownish yellow, with pale yellow legs.

Description of Worker

(Character states in boldface contrast with the worker of *V. philippina*, the other formally named Philippines species)

Head longer than broad, **lateral margins behind eyes subparallel**; dorsum rugoreticulate, **with microreticulate interstices**. Torulus obscured by short, narrow frontal lobes. Antennal scrobes **shallow, with smaller reticulation than head dorsum, dorsally bordered by frontal carinae that are scarcely more pronounced than rugoreticulum**. Subocular groove complete, **almost straight**. Clypeus reticulate, convex in lateral view; in full-face view, true anterior clypeal margin medially convex **but not obscured by convexity of clypeus**. Compound eye with 8-9 ommatidia in longest row. Mandibles smooth, with faint longitudinal striation. Dorsum of mesosoma, petiole and postpetiole with coarse rugoreticulum. In lateral view, **dorsum of mesosoma weakly convex**; metanotal groove obsolete; propodeum follows the slight curvature of the mesosomal outline; propodeal declivity sharply sloped downward; propodeal spines situated at the top of the propodeal declivity, distinctly curved in dorsal view; propodeal spiracle **high on the side**, well separated from the metapleural gland bulla; petiolar peduncle **without teeth protecting petiolar spiracle**; petiolar spiracle at about midlength of peduncle; dorsal face of peduncle **forming a very obtuse angle with the anterior face of petiolar node**; subpetiolar and subpostpetiolar processes present. In dorsal view, postpetiole subtrapezoidal, widest anteriorly. Gaster ovate, dorsally smooth except for short basigastral costulae, with blunt erect setae slightly shorter than those on mesosoma. Sting simple and functional.

Pilosity: Dorsum of head and body with long erect blunt setae. Setae on dorsum of mesosoma, petiole, and postpetiole longer than those on head dorsum.



Figures 1-4. *Vombisidris freya* sp. n.: 1. Head in full-face view; 2. Lateral habitus; 3. Dorsal habitus; 4. Labels.

Colour: Head, body, gaster, mandibles, and antennae **golden yellow**; legs **light yellow**.

Type material examined

Holotype worker: PHILIPPINES: Camarines Sur Province, Mt. Isarog Natural Park, Municipality of Pili, Del Rosario Village, 600 masl, 23-ii-2019, leg. D. E. M. General, et al. (deposited at UPLB: UPLBMNH HYM-01757).

Paratype workers: (n=2) same data as holotype; one each deposited at PNM (UPLBMNH HYM-01758 and PNM 14018) and MCZC (UPLBMNH HYM-01759).

Bionomics

This species was collected only during nocturnal beating of low vegetation in a transect study (General *et al.*, 2020), suggesting that *V. freya* sp. n. is a nocturnal, arboreal forager.

Etymology

This species is lovingly dedicated to the author's granddaughter, Freya Marie General Booth.

Comparative Notes

The morphological differences between the workers of *V. philippina* and *V. freya* sp. n. are presented in the key above and in the species description. In addition, *V. freya* sp. n. has a larger mesosoma (mean WL 0.88 mm, mean PW 0.45 mm) than *V. philippina* (range WL 0.80-0.85 mm, range PW 0.40-0.44 mm) (Zettel and Sorger, 2010). Despite the presence of a shallow antennal scrobe, this ant belongs to the genus *Vombisidris* (B. Bolton, personal communication). *Vombisidris freya* sp. n. is the second species formally described from the Philippines. It is unclear whether *Vombisidris* sp. A sensu Zettel and Sorger (2010) is conspecific with this new species.

In Bolton's (1991) key, *V. freya* sp. n. arrives at couplet 11 that separates *V. harpeza* Bolton, 1991 from *V. occidua* Bolton, 1991. *Vombisidris freya* sp. n. differs from *V. occidua* in possessing stiff, erect blunt setae on the dorsum of the head and mesosoma as well as being golden yellow. *Vombisidris freya* sp. n. is more similar to *V. harpeza* [image of holotype from AntWeb (2020)] but possesses an almost straight sub-ocular groove, and in which the metanotal groove is obsolete.

Vombisidris freya **sp. n.** fails to key out at couplet #9 of Xu and Yu (2012) because both *V. nahet* Bolton, 1991 and *V. regina* Bolton, 1991 have sinuate sub-ocular grooves while *V. freya* **sp. n.** has an almost straight sub-ocular groove.

Discussion

Vombisidris freya **sp. n.** was discovered by modifying a collecting technique to target nocturnal arboreal ants and other arthropods (General *et al.*, 2020). This species was referred to as “*Vombisidris* sp1” in General *et al.* (2020).

It is possible that other *Vombisidris* species are nocturnal arboreal foragers, explaining the rarity of the genus in collections. Other rare genera may also be simply nocturnal, escaping the attention of field researchers. The primitive *Nothomyrmecia macrops* Clark, 1934 was rediscovered when foraging ants were observed on eucalyptus trees at night (Taylor, 1978). Further observations and field work by Taylor (1978) showed that *N. macrops* was strictly nocturnal. Observing a nest fragment in a laboratory setting, Wong and Yong (2017) found that *Tyrannomyrmex rex* Fernández, 2003 ants forage at night, while clustering in the artificial nest during the day.

The nocturnal behavior of certain ant species may explain the rarity of these species in collections. The ants may be active when field researchers are already back in camp. The rarity of *Vombisidris* ants may just be an artifact of sampling bias (B. Bolton, personal communication).

Sampling arboreal ants at night may detect the presence of *Vombisidris* and other rare genera in other localities.

Acknowledgments

I thank Barry Bolton for correcting my initial genus identification and for a short comment on the nocturnal behavior of ants. I also thank the Metro Naga Water District for allowing access to their watershed and generously providing my group with their field personnel for porters, guides, and cooks. I also thank the Department of Environment and Natural Resources, Region V for issuing a Gratuitous Permit (GP# R5-105) to me. I especially appreciate the assistance in the field by Perry Archival C. Buenavente, Arvin C. Diesmos, Jasmin C. Meren, Yñigo C. del

Prado, Rolly C. Urriza, Roylan C. Urriza, and Emerson Y. Sy. I also thank Nicole Bechayda for sorting the ant specimens of our collection to genus. I am especially grateful to Perry Archival C. Buenavente for creating and post-processing the images. Finally, I am grateful to my institution for allowing me to conduct field work. This work was partly funded by the UP System Enhanced Creative Work and Research Grant (ECWRG 2018-1-013) to DEMG.

References

- AntWeb. 2020. <<http://www.antweb.org>>, accessed on 27 March 2020.
- Bolton, B. 1991. New myrmicine ant genera from the Oriental region. *Systematic Entomology* 16: 1-13.
- Bolton, B. 2020. An online catalogue of the ants of the world. Accessed at <http://antcat.org> on 6 April 2020.
- Brandão, C.R.F. 2000. Major regional and type collections of ants (Formicidae) of the world and sources for the identification of ant species. *In*: D. Agosti, J.D. Majer, L.E. Alonso & T.R. Schultz (eds.) *Ants: standard methods for measuring and monitoring biodiversity*. Washington, DC: Smithsonian Institution Press, 172-185.
- General, D.E.M., Buenavente, P.A.C. and Rodriguez, L.J.V. 2020. A preliminary survey of nocturnal ants, with novel modifications for collecting nocturnal arboreal ants. *Halteres* 11: 1-12.
- Taylor, R.W. 1978. *Nothomyrmecia macrops*: a living fossil-ant rediscovered. *Science* 201: 979-985.
- Xu, Z-H. and Yu, N-N. 2012. *Vombisidris tibeta*, a new myrmicine ant species from Tibet, China with a key to the known species of *Vombisidris* Bolton of the world (Hymenoptera: Formicidae). *Sociobiology* 59(4): 1495-1507.
- Wong, M.K.L. and Yong, G.W.J. 2017. Notes on the habitat and biology of the rare ant genus *Tyrannomyrmex* (Fernandez, 2003). *Asian Myrmecology* 9 e009007: 1-4.
- Zettel, H. and Sorger, D.M. 2010. On the ants (Hymenoptera: Formicidae) of the Philippine Islands. IV. The genus *Vombisidris* Bolton, 1991. *Entomologica Austriaca* 17: 37-44.

An updated checklist of Vespidae (Insecta: Hymenoptera) from Arunachal Pradesh, India with new distributional records from the State

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Abstract

An updated checklist of 69 species from 26 genera and 4 subfamilies of Vespidae from Arunachal Pradesh is provided in this study. Four species, viz. *Eumenes macrops* de Saussure, *Polistes (Polistella) adustus* Bingham, *Polistes (Polistella) rubellus* Gusenleitner, and *Vespula germanica* (Fabricius), are documented for the first time from Arunachal Pradesh.

Keywords: *Hymenoptera, New records, Arunachal Pradesh, Checklist.*

Received: 20 January 2020; Revised: 24 September 2020; Online: 28 September 2020

Introduction

Arunachal Pradesh is the eastern most state of India and among the biodiversity hotspots at India (Myers *et al.*, 2000). The location of the state with topographical and climatological uniqueness made the state as one of the most species rich regions of the country.

Family Vespidae belongs to the order Hymenoptera with 5000 species recorded globally, with six subfamilies, viz. Eumeninae, Vespinae, Polistinae, Masarinae, Stenogastrinae and Euparagiinae (Goulet & Huber, 1993) and is represented by 150 species under 40 genera from the Indian Himalayan region (Chandra *et al.*, 2018). Reports of Vespidae from Arunachal Pradesh is however scattered and scanty. The earlier work done by Bingham (1897), Roy & Kundu (1985), Das & Gupta (1989), Kundu *et al.* (2006), Singh *et al.* (2010), Srinivasan & Girish Kumar (2010), Kenny *et al.* (2019) and Gawas *et al.* (2020) reflected documentation of few species for the state, altogether 65 species of Vespidae have been reported from Arunachal Pradesh. Present study reports new distributional records of four species from the state taking the tally to 69 species belonging to 26 genera from 4 subfamilies. Along with brief description of the new records from the

state, an updated checklist of Vespidae from Arunachal Pradesh is provided through the present work.

Materials and Methods

Surveys were undertaken in different parts of Indian Himalayan region, as part of the NMHS- Biodiversity assessment project. However, in this study, specimens collected from Arunachal Pradesh are only taken into account. Wasps were collected, narcotised with ethyl acetate and subsequently stored in 70% ethyl alcohol. Specimens were then taken to the laboratory, properly stretched, pinned and identification was done following Bingham (1897), Das & Gupta (1989), Gusenleitner (2006), Fabricius (1793), Girish Kumar *et al.* (2017) and then compared with reference collections from Zoological Survey of India, Western Ghats Regional Centre, Kozhikode (ZSIK). All the specimens were examined and photographed under Leica stereo zoom microscope and labelled with Adobe Photoshop v7.0.

Taxonomic classification is followed as in Carpenter (1982). The different morphological terms that are used for describing the specimen followed Das & Gupta (1989) and Girish Kumar *et al.* (2017).

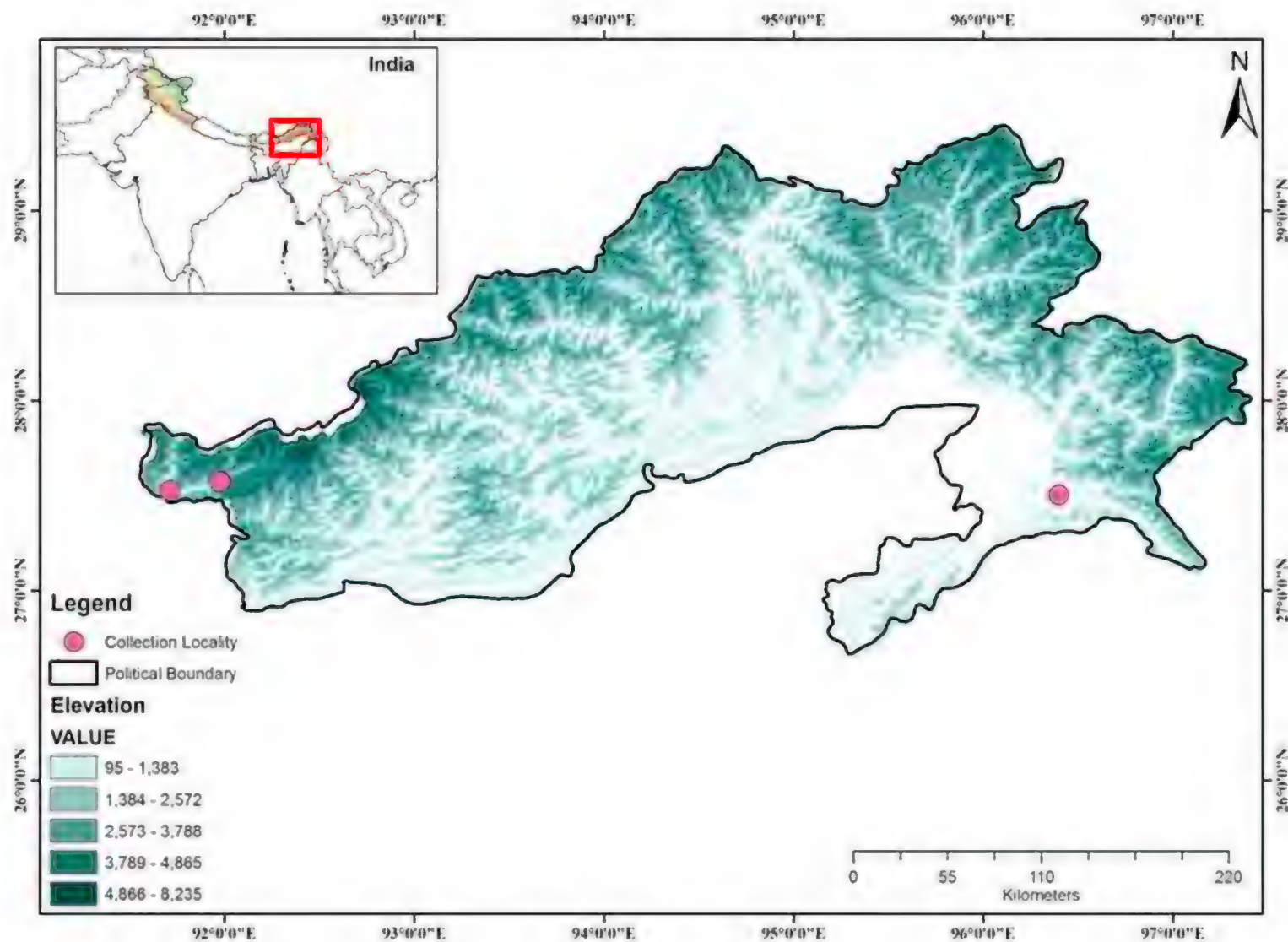


Figure 1. Collection localities of Family Vespidae from Arunachal Pradesh, India.

Abbreviations used

BL: Body Length; BMNH: The Natural History Museum, formerly British Museum (Natural History), London, Great Britain; FWL: Fore Wing Length; OLM: Oberösterreichischen Landesmuseum, Linz, Austria; ZSIK: Zoological Survey of India, Western Ghats Regional Centre, Kozhikode, Kerala, India.

Results

Taxonomic Account

Order Hymenoptera

Family Vespidae

Subfamily Eumeninae

Genus *Eumenes* Latreille, 1802

Eumenes macrops de Saussure (Fig. 2A-D)

Eumenes macrops de Saussure, 1852: 41, ♂—
“La Caroline du nord” (BMNH).

Material examined: Registration No.22424/H3 and 22425/H3, 1 Male and 1 Female, 13.iii.2017, 27.506 N, 96.396 E, Alt. 345.4 metres, Deban, Namdapha National Park, Changlang, Arunachal Pradesh, India, coll. J. Saini & Party.

Male: **BL** 14.8mm; **FWL** 9.1 mm.

Female: **BL** 11.7 mm; **FWL** 8.2 mm.

Diagnosis: Legs almost entirely ferruginous (coxae and trochanter black), rarely with few yellow markings on fore and mid leg; punctuation of second tergum relatively coarse and not very dense; second tergum, in profile, little swollen in middle, weakly impressed preapically, and apical margin slightly reflected; in male, apical antennal article hooked, its apex reaching middle of 10th segment in curved position.

Distribution: India: Arunachal Pradesh (present record), Assam, Karnataka, Kerala, Maharashtra, Nagaland, Pondicherry, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal. *Elsewhere:* Indonesia; Malaysia; Myanmar. (Girish Kumar *et al.*, 2017).

Remarks: This is one of the widely distributed potter wasp in India. First time reported from Arunachal Pradesh.

Subfamily Polistinae

Tribe Polistini

Genus *Polistes* Latreille, 1802

Subgenus *Polistella* Ashmead, 1904

Polistes (Polistella) adustus Bingham, 1897 (Fig. 3A-D)

Polistes adustus Bingham, 1897: 397, ♀, holotype, "Sikkim, up to 6000 feet" (BMNH).

Material examined: Registration No.22426/H3, 1 Male, 21.ix.2018, 27.578 N, 91.976 E, Alt. 2274 metres, Jung, Tawang, Arunachal Pradesh, India, coll. S. Ahmed & Party.

BL 14.9mm; **FWL** 11.3 mm.

Diagnosis: Metasoma black with broad red band on apical margin of first to fifth tergum; scutellum more or less raised, elevated from the level of mesoscutum; second sternum angular at base, propodeum with sharp lateral edges; legs not completely black. In males, sub genital plate with central tubercle.

Distribution: India: Arunachal Pradesh (present record), Delhi, Himachal Pradesh, Jammu & Kashmir, Meghalaya, Sikkim, Uttarakhand, West Bengal. *Elsewhere:* Bhutan; China; Nepal (Das & Gupta, 1989).

Remarks: This species is distributed in Himalaya and adjacent regions. First time reported from Arunachal Pradesh.

***Polistes (Polistella) rubellus* Gusenleitner, 2006 (Fig. 4A-D)**

Polistes rubellus Gusenleitner 2006: 684, ♀, holotype, Yuksam 8 km S, W-Sikkim, India [OLM].

Material examined: Registration No.22427/H3, 1 Female, 21.ix.2018, 27.575 N, 91.973 E, Alt. 2271 metres, Jung, Tawang, Arunachal Pradesh, India, coll. S. Ahmed & Party.

BL 15.2 mm; **FWL** 11.9 mm.

Diagnosis: Second sternum behind the basal furrow, in side view, not angular, only strongly curved; propodeum with strong transverse striations; base of metanotum with distinct transverse carina; metasoma bicoloured: black and ferruginous.

Distribution: India: Arunachal Pradesh (present record), Sikkim. *Elsewhere:* Nepal (Gusenleitner, 2006; Nguyen *et al.*, 2011).

Remarks: This is a Himalayan species with a limited distributional record. First time reported from Arunachal Pradesh.

Subfamily Vespinae

Genus *Vespula* Thomson, 1869

***Vespula germanica* (Fabricius, 1793)**

(Fig. 5A-D)

Vespa germanica Fabricius, 1793: 256 - [Germany] "Kiliae" (type depository unknown).

Material examined: Registration No. 22429/H3, 1 Female, 21.iv.2018, 27.578 N, 91.976 E, Alt. 2274 metres, Jung, Tawang, Arunachal Pradesh, India, coll. J. Saini & Party.

BL 22.4 mm; **FWL** 14.1 mm.

Diagnosis: Margin behind third mandibular tooth distinctly concave; outer basal flange of mandible strongly curved; occipital carina reaching mandibular base; apical margin of clypeus concave and depressed medially; mesosomal punctures indistinct; propodeum not rugose.

Distribution: India: Arunachal Pradesh (present record), Himachal Pradesh, Jammu & Kashmir. *Elsewhere:* Afghanistan; Albania; Algeria; Armenia; Argentina (Introduced); Ascension Island (Introduced); Australia (Introduced); Austria; Azerbaijan; Belarus; Belgium; Bosnia & Herzegovina; Bulgaria; Canada (Introduced); Chile (Introduced); China; Croatia; Czech Republic; Denmark; Estonia; Finland; France; Georgia; Germany; Greece; Hungary; Iceland (Introduced); Iran; Iraq; Ireland; Israel; Italy; Jordan; Kazakhstan; Korea; Kyrgyzstan; Lebanon; Liechtenstein; Lithuania; Luxembourg; Macedonia; Malta; Mayotte; Moldova; Mongolia; Morocco; Nepal; Netherlands; New Zealand (Introduced); Norway; Pakistan; Poland; Portugal; Romania; Russia; Sakhalin Island; Scotland; Serbia; Slovakia; Slovenia; South Africa (Introduced); Spain (including Canary Islands); Sweden; Switzerland; Syria; Taiwan; Tajikistan; Tunisia; Turkey; Turkmenistan; U.K.; Ukraine; U.S.A. (Introduced); Uzbekistan (Girish Kumar and Carpenter, 2018).



Figure 2. *Eumenes macrops* de Saussure: **A.** Habitus; **B.** Head, Frontal View; **C.** Head and Mesosoma, Dorsal View; **D.** Metasoma, Lateral View.



Figure 3. *Polistes (Polistella) adustus* Bingham 1897: **A.** Habitus; **B.** Head, Frontal View; **C.** Head and Mesosoma, Dorsal View; **D.** Metasoma, Lateral View.

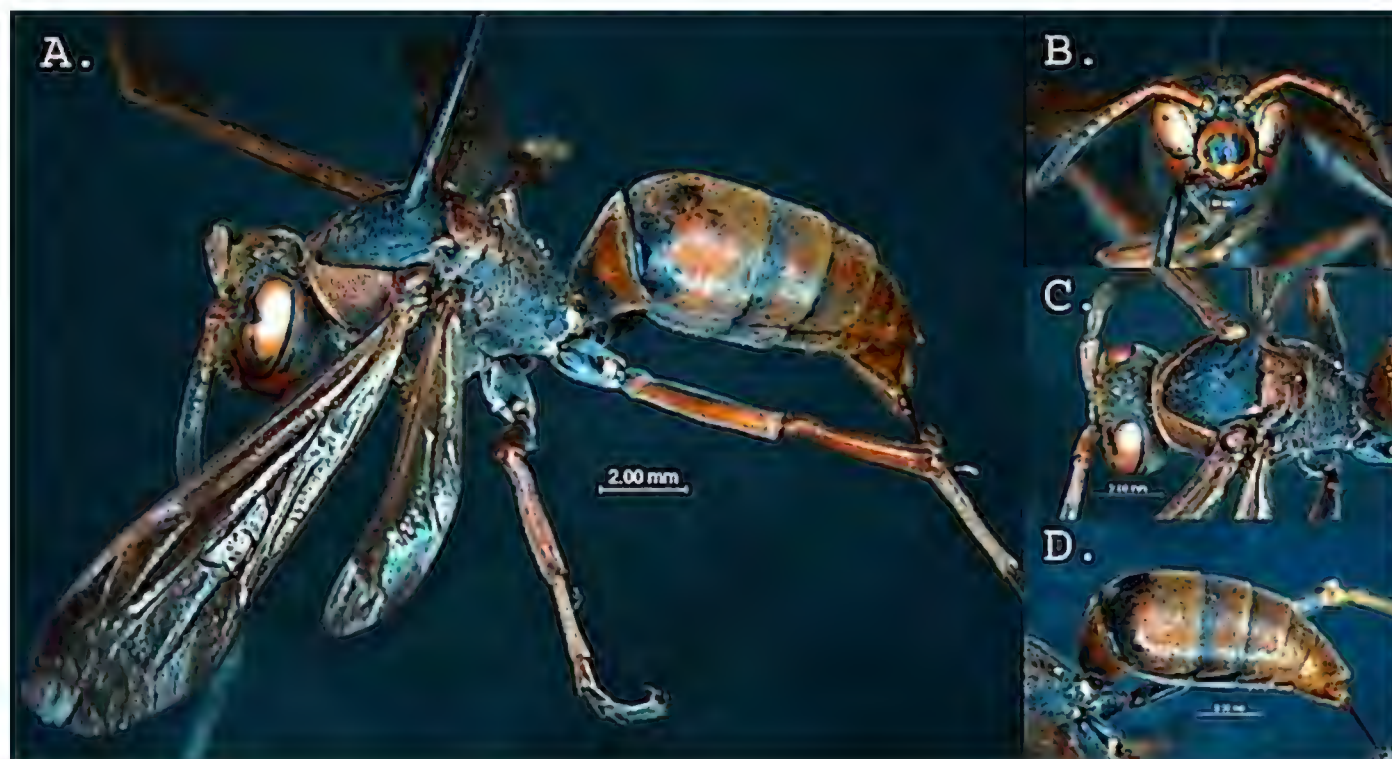


Figure 4. *Polistes (Polistella) rubellus* Gusenleitner, 2006: **A.** Habitus; **B.** Head, Frontal View; **C.** Head and Mesosoma, Dorsal View; **D.** Metasoma, Lateral View.



Figure 5. *Vespa germanica* (Fabricius, 1793): **A.** Habitus; **B.** Head, Frontal View; **C.** Head and Mesosoma, Dorsal View; **D.** Metasoma, Lateral View.

Remarks: *V. garmanica* is a common European (Palearctic) species. Being invasive, except Antarctica, widely introduced to all of the continents. Previously reported from Kashmir, India (Lester & Beggs, 2019). First time recorded from Arunachal Pradesh.

Discussion

According to the generic and species diversity of family Vespidae from Arunachal Pradesh, the most speciose subfamily

Eumeninae has 30 species belonging to 17 genera, followed by Polistinae with 20 species under 3 genera, Vespinae with 16 species from 3 genera and Stenogastrinae with 3 species belonging to 3 genera (Fig.6). Being a biodiversity hotspot, Arunachal Pradesh harbours a vast range of faunal diversity which is yet to be discovered. So, it is imperative that further intensive sampling effort is needed in order to discover all the faunal resources from the region.

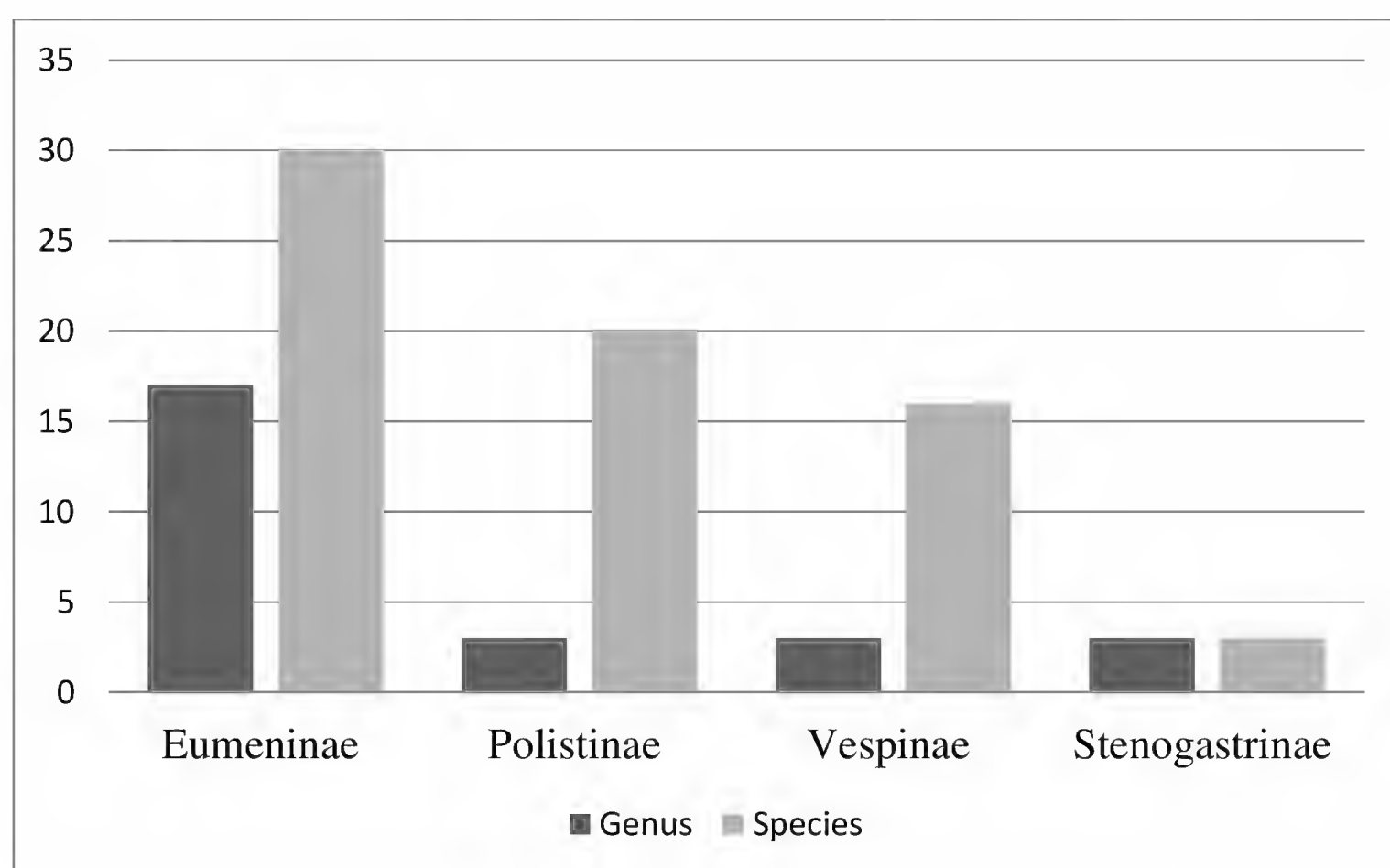


Figure 6. Generic and species diversity of Vespidae subfamilies in Arunachal Pradesh, India.

AN ANNOTATED DISTRIBUTIONAL
CHECKLIST OF VESPIDAE
(HYMENOPTERA: VESPOIDEA) OF
ARUNACHAL PRADESH
SUBFAMILY: EUMENINAE
TRIBE: EUMENINI

1. Genus *Delta* de Saussure, 1855

1. *Delta companiforme companiforme* (Fabricius, 1775)
2. *Delta conoideum* (Gmelin, 1790)
3. *Delta dimidiatipenne* (de Saussure, 1852)
4. *Delta esuriens* (Fabricius, 1787)
5. *Delta pyriforme pyriforme* (Fabricius, 1775)

2. Genus *Eumenes* Latreille, 1802

6. *Eumenes architectus* Smith, 1859 [kept as doubtful species from India; see Girish Kumar *et al.*, 2017]
7. *Eumenes assamensis* Meade-Waldo, 1910
8. *Eumenes atrophicus* (Fabricius, 1798)
9. *Eumenes punctatus* de Saussure, 1852
10. *Eumenes macrops* de Saussure, 1852 (new record)

3. Genus *Phimenes* Giordani Soika, 1992

11. *Phimenes flavopictus* (Blanchard, 1845)

TRIBE: ODYNERINI

4. Genus *Allorhynchium* van der Vecht, 1963

12. *Allorhynchium argentatum* (Fabricius, 1804)

5. Genus *Antepipona* de Saussure, 1855

13. *Antepipona biguttata* (Fabricius, 1787)
14. *Antepipona bipustulata* (de Saussure, 1855)

6. Genus *Anterhynchium* de Saussure, 1863

15. *Anterhynchium* (*Dirhynchium*) *flavolineatum* (Smith, 1857)

7. Genus *Antodynerus* de Saussure, 1855

16. *Antodynerus limbatus* (de Saussure, 1852)

8. Genus *Apodynerus* Giordani Soika, 1993

17. *Apodynerus formosensis indicus* Giordani Soika, 1994
18. *Apodynerus troglodytes troglodytes* (de Saussure, 1856)

9. Genus *Labus* de Saussure, 1867

19. *Labus humbertianus* de Saussure, 1867
20. *Labus pusillus* van der Vecht, 1963

10. Genus *Orancistrocerus* van der Vecht, 1963

21. *Orancistrocerus aterrimus khasianus* (Cameron, 1900)

11. Genus *Paraleptomenes* Giordani Soika, 1970

22. *Paraleptomenes darugiriensis* Girish Kumar *et al.*, 2014

23. *Paraleptomenes rufoniger* Giordani Soika, 1994

12. Genus *Parancistrocerus* Bequaert, 1925

24. *Parancistrocerus holzschuhi* Gutsenleitner, 1987

13. Genus *Pararrhynchium* de Saussure, 1855

25. *Pararrhynchium venkataramani* Girish Kumar and Carpenter, 2017

14. Genus *Pareumenes* de Saussure, 1855

26. *Pareumenes quadrispinosus acutus* Liu, 1941
27. *Pareumenes quadrispinosus quadrispinosus* (de Saussure, 1855)

15. Genus *Rhynchium* Spinola, 1806

28. *Rhynchium brunneum* (Fabricius, 1793)

16. Genus *Subancistrocerus* de Saussure, 1855

29. *Subancistrocerus sichelii* (de Saussure, 1856)

17. Genus *Tropidodynerus* Blüthgen, 1939

30. *Tropidodynerus* (*Tropidepipona*) *fraternus* (Bingham, 1897)

SUBFAMILY: POLISTINAE

TRIBE: POLISTINI

18. Genus *Polistes* Latreille, 1802

Subgenus *Gyrostoma* Kirby, 1828

31. *Polistes* (*Gyrostoma*) *olivaceus* (De Geer, 1773)
32. *Polistes* (*Gyrostoma*) *tenebricosus* Lepeletier, 1836
33. *Polistes* (*Gyrostoma*) *rothneyi carletoni* van der Vecht, 1968

Subgenus *Polistella* Ashmead, 1904

34. *Polistes* (*Polistella*) *dawnae* Dover and Rao, 1922
35. *Polistes* (*Polistella*) *nigritarsis* Cameron, 1900
36. *Polistes* (*Polistella*) *sagittarius* de Saussure, 1854
37. *Polistes* (*Polistella*) *adustus* Bingham, 1897 (new record)
38. *Polistes* (*Polistella*) *rubellus* Gutsenleitner, 2006 (new record)

TRIBE: POLYBIINI

19. Genus *Parapolybia* de Saussure, 1853

39. *Parapolybia indica* (de Saussure, 1854)
40. *Parapolybia varia* (Fabricius, 1787)
41. *Parapolybia tinctipennis* (Cameron, 1900)

TRIBE: ROPALIDIINI

20. Genus *Ropalidia* Guérin-Ménéville, 1831

42. *Ropalidia cyathiformis* (Fabricius, 1804)
43. *Ropalidia brevita* Das & Gupta, 1989

44. *Ropalidia fasciata* (Fabricius, 1804)
45. *Ropalidia jacobsoni* (du Buysson, 1908)
46. *Ropalidia ornaticeps* (Cameron, 1900)
47. *Ropalidia rufocollaris* (Cameron, 1900)
48. *Ropalidia santoshae* (Das and Gupta, 1989)
49. *Ropalidia scitula* (Bingham, 1897)
50. *Ropalidia stigma* (Smith, 1858)

SUBFAMILY: STENOGASTRINAE

21. Genus *Cochlischnogaster* Dong & Otsuka, 1997

51. *Cochlischnogaster dadugangensis* Dong and Otsuka, 1997

22. Genus *Eustenogaster* van der Vecht, 1969

52. *Eustenogaster scitula* (Bingham, 1897)

23. Genus *Parischnogaster* von Schulthess, 1914

53. *Parischnogaster mellyi* (de Saussure, 1852)

SUBFAMILY: VESPINAE

24. Genus *Provespa* Ashmead, 1903

54. *Provespa barthelemyi* (du Buysson, 1905)

25. Genus *Vespa* Linnaeus, 1758

55. *Vespa affinis* (Linnaeus, 1764)
56. *Vespa analis* Fabricius, 1775
57. *Vespa auraria* Smith, 1852
58. *Vespa basalis* Smith, 1852
59. *Vespa bicolor* Fabricius, 1787
60. *Vespa binghami* du Buysson, 1905
61. *Vespa fumida* van der Vecht, 1905
62. *Vespa mandarinia* Smith, 1852
63. *Vespa soror* du Buysson, 1905
64. *Vespa tropica* (Linnaeus, 1758)
65. *Vespa velutina* Lepeletier, 1836

26. Genus *Vespula* Thomson, 1896

66. *Vespula flaviceps* (Smith, 1870)
67. *Vespula orbata* (du Buysson, 1902)
68. *Vespula structor* (Smith, 1870)
69. *Vespula germanica* (Fabricius, 1793) (new record)

Acknowledgements

The authors sincerely thank the Director, Zoological Survey of India, Kolkata, for providing facilities and encouragements. The study was funded by MoEF & CC under National Mission for Himalayan Studies (NMHS) programme entitled “Biodiversity Assessment through long term monitoring plots in Indian Himalayan Landscape” (Ref. No. NMHS/LG-2016/0011). We wish to convey our gratitude to the Forest Department

of Arunachal Pradesh for providing necessary permissions for field surveys. Authors are thankful to Gaurab Nandi Das for his inputs for image processing.

References

- Bingham, C.T. 1897. Fauna of British India, including Ceylon and Burma, Hymenoptera, Wasps and bees. Taylor and Francis, London, 579 pp. + xxiv.
- Carpenter, J.M. 1982. The phylogenetic relationships and natural classification of the Vespoidea (Hymenoptera). Systematic Entomology 7(1): 11-38.
- Chandra, K., Gupta, D., Gopi, K.C., Tripathy, B. & Kumar, V. 2018. Faunal Diversity of Indian Himalaya. Kolkata: Zoological Survey of India, 1-872.
- Das, B.P. & Gupta, V.K. 1989. The Social Wasps of India and the Adjacent Countries (Hymenoptera: Vespidae). Oriental Insects Monograph 11. Gainesville: The Association for the Study of Oriental Insects, 292 pp.
- Fabricius, J.C. 1793. Entomologia Systematica Emendata Et Aucta: Secundum Classes, Ordines, Genera, Species Aadjectis Synonymis, Locis, Observationibus, Descriptionibus (Vol. 2). Proft.
- Gawas, S.M., Girish Kumar, P., Pannure, A. & Carpenter, J.M. 2020. An annotated distributional checklist of Vespidae (Hymenoptera: Vespoidea) of India. Zootaxa 4784(1): 1-87. DOI: <https://doi.org/10.11646/zootaxa.4784.1.1>
- Girish Kumar, P. & Carpenter, J.M. 2018. A taxonomic review of the genus *Vespula* Thomson (Hymenoptera: Vespidae: Vespinae) from the Indian subcontinent. Halteres 9: 86-110. DOI: <https://doi.org/10.5281/zenodo.1258043>
- Girish Kumar, P., Carpenter, J.M., Castro, L., & Sureshan, P.M. 2017. A taxonomic review of the Indian species of the genus *Eumenes* Latreille (Hymenoptera: Vespidae: Eumeninae). Zootaxa 4317(3): 469-498. DOI: <http://dx.doi.org/10.11646/zootaxa.4317.3.3>
- Goulet, H. & Huber, J.T. 1993. Hymenoptera of the world: an identification guide to families of Hymenoptera. Canada Communication Group – Publishing, Ottawa, 667 pp.

- Gusenleitner, J. 2006. Über Aufsammlungen von Faltenwespen in Indien (Hymenoptera: Vespidae). Linzer Biologische Beiträge 38(1): 677–695.
- Horne, C. & Smith, F. 1870. Notes on the habits of some hymenopterous insects from the north-west provinces of India. With an appendix, containing descriptions of some new species of Apidae and Vespidae collected by Mr. Horne: by Frederick Smith, of the British Museum. Transactions of the Zoological Society of London 7: 161-196, pls. 19-22.
- Kenny, S., Gawas, S.M., Ankita, G. and Shaw, S.S. 2019. Checklist of vespid wasps (Hymenoptera: Vespidae) of Arunachal Pradesh, India, with a new distribution record of *Vespula flaviceps* (Smith). Journal of Biological Control 33(4): 336-342. DOI: 10.18311/jbc/2019/24148
- Kundu, B.G., Ghosh, S.N. & Roy Chowdhury, S. 2006. Insecta: Hymenoptera: Aculeata (Vespidae and Apidae). Zoological Survey of India, Fauna of Arunachal Pradesh, State Fauna Series 13(2): 427-448.
- Lester, P.J. & Beggs, J.R. 2019. Invasion success and management strategies for social *Vespula* wasps. Annual review of entomology 64: 51-71. DOI: 10.1146/annurev-ento-011118-111812.
- Myers, N., Mittermeier, R.A., Mittermeier, C.A., da Fonseca, G.A.B. & Kent, J. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853-858.
- Nguyen, L.T.P., Kojima, J.I. & Saito, F. 2011. *Polistes* (*Polistella*) wasps (Hymenoptera: Vespidae: Polistinae) from mountainous areas of northern Vietnam, with description of five new species. Zootaxa 3060: 1-30.
- Roy, S.B. & Kundu, B.G. 1985. Fauna of Namdhapa, Arunachal Pradesh, India (Insecta: Hymenoptera), Records of the Zoological Survey of India 82(1-4): 221-229.
- Saussure, H. de. 1852–1853. *Études sur la famille des Vespides 1: Monographie des Guêpes solitaires ou de la tribu des Euméniens*. J. Cherbuliez, Genève & V. Masson, Paris, i–xix + 1–286 pp. + 22 pls. (1852) 1–128 + pl. 2–5, 7, 10, 14; (1853) i–xix + 129–286 + pl. 1, 6, 8, 9, 11–13, 15–22.
- Singh, O.T., Chakravorty, J. & Varatharajan, R. 2010. Entomofauna of Kane Wildlife Sanctuary, Arunachal Pradesh, northeastern India (7 species). Journal of Threatened Taxa 2(13): 1392-1400. DOI: <https://doi.org/10.11609/JoTT.o1946.1392-400>
- Srinivasan, G. & Girish Kumar, P. 2010. New records of potter wasps (Hymenoptera: Vespidae: Eumeninae) from Arunachal Pradesh, India: five genera and ten species. Journal of Threatened Taxa 12(2):1323-1324. DOI: <https://doi.org/10.11609/JoTT.o2468.1313-22>.

Facultative associations of two sympatric lycaenid butterflies with *Camponotus compressus* – field study and larval surface ultrastructure

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Abstract

The present study focused on the associations of two sympatric lycaenid species, *Chilades pandava* Horsfield, 1829 and *Euchrysops cnejus* Fabricius, 1798 with their respective host plants and the lycaenid tending *Camponotus compressus* Fabricius, 1787 ants by conduction of field studies and by examination of the ultrastructure of the larval myrmecophilous organs. The study revealed two facultative association complexes: ants - the defoliating *Cl. pandava* larvae - *Cycas revoluta* (Thunb.) plants and ants - the pod-boring *E. cnejus* larvae - cowpea plant, *Vigna unguiculata* (L.) Walp. The association of *Cl. pandava* was strongly synchronized with its host plant phenology and relatively less strongly with its late-arriving ant partner since the young, curled up leaves provided resources only to the caterpillars. The provision of resources to both the ants and the lycaenids by the cowpea plants contributed to the synchronization of *E. cnejus* association with the early arriving ants as well as the host plant. Presence of a single type of setae in *Cl. pandava* and of two types of setae in *E. cnejus* larvae indicates their facultative adaptations for resisting attack by their host ants. Ultrastructural similarity in the dorsal nectary, pore cupola and tentacle organs suggest that the basic myrmecophilous organs are conserved in these two lycaenid species.

Keywords: ants; *Euchrysops cnejus*; *Chilades pandava*; scanning electron microscopy; myrmecophilous organs.

Received: 10 January 2020; Revised: 24 September 2020; Online: 28 September 2020

Introduction

The myrmecophilous butterfly family Lycaenidae accounts for approximately a quarter of the global butterfly species richness (Pierce *et al.*, 2002). About 60% of the lycaenid myrmecophiles are associated with several ant species (Pierce *et al.*, 2002). The association between ants and the lycaenid larvae ranges from facultative (Saarinen & Daniels, 2006; Bächtold *et al.*, 2014; Hojo *et al.*, 2014) to obligate (Als *et al.*, 2002; Pierce *et al.*, 2002; Steiner *et al.*, 2003; Martins *et al.*, 2013). Many species of lycaenids are involved in food for-protection mutualistic relationships with ants. Myrmecophily involves both behavioural as well as morphological adaptations of the lycaenid caterpillars which possess a suite of anatomical structures for maintaining association with ants (Fiedler *et al.*, 1996; Pierce *et al.*, 2002; Trager & Daniels, 2009). Ant attendance of third/fourth

instar larvae is primarily sustained by gustatory and/or semiochemical mediation involving at least three types of ant-associated organs: the pore cupola organs (PCOs) present across the abdomen; the dorsal nectary organ (DNO) on the seventh abdominal segment; and a pair of tentacle organs (TOs) on the eighth abdominal segment (Kitching & Luke, 1985; Leimar & Axen, 1993; Axen *et al.*, 1996; Hojo *et al.*, 2008, 2009). These serve primarily as appeasement organs and help to avoid predation from the ants (Dupont *et al.*, 2016).

The myrmecophilous lycaenid caterpillars are tended by the associated ant species, usually on the larval host plants, where the herbivorous larvae encounter the plant-visiting worker ants (Pierce *et al.*, 2002). Lycaenids demonstrate considerable variations in their host plant range and their larval stages

are specialist feeders of tender foliage or inflorescence (Fiedler, 1996). Hence, the host plant phenology and seasonal predictability in the availability of the larvae preferred plant resources (food and/or shelter) is likely to play an important role in ant-lycaenid-host plant association.

A large number of facultative ant-lycaenid associations involve plant-visiting ants belonging to the genus *Camponotus* (Saarinen & Daniels, 2006; Bächtold *et al.*, 2014; Hojo *et al.*, 2014). *Camponotus compressus* is distributed across Africa and Asia and is widespread in many parts of India (Agarwal & Rastogi, 2010; Bharti *et al.*, 2016; Ekka & Rastogi, 2017). Our preliminary observations revealed the association of *C. compressus* with caterpillars of two sympatric lycaenid butterflies: *Chilades pandava* Horsfield and *Euchrysops cnejus* Fabricius. While the larvae of *Cl. pandava* are defoliators of cycads, plants belonging to family Fabaceae are also preferred host plants (Robinson *et al.*, 2010; Marler, 2012). *E. cnejus* larvae are pod-boring pests which prefer various species of legumes belonging to the Fabaceae family (Robinson *et al.*, 2010; Tiple *et al.*, 2011). The respective locally available host plants of *Cl. pandava* and *E. cnejus* were *Cycas revoluta* and *Vigna unguiculata*.

Elucidation of myrmecophily requires a basic understanding of the natural history of ant-lycaenid-host plant complex as well as the ultrastructural details of the specialized myrmecophilous organs possessed by the fourth instar lycaenid larvae as adaptations related to their association with ants. Ant, lycaenid and the host plant association involves three partners but the emphasis of majority of studies has been mainly on the ant-lycaenid myrmecophilous aspects (Pierce *et al.*, 2002; Fiedler, 2012). For survival, the lycaenid larvae need both food and protection from enemies. Only few studies have examined the influence of host plants on myrmecophilous associations (Fiedler, 1996). Since lycaenid juveniles feed on various types of host plants, the species specific role of host plant phenology on the extent of larval dependence on each of its two associates: the host plant and the ant body guards, needs to be deciphered. Concurrently, it is also essential to examine if the ultrastructural details of the myrmecophilous

organs are influenced by variations in the larval association with ants. In view of the constraints imposed by the narrow host plant range of *Cl. pandava* and *E. cnejus*, we hypothesize that the strength of the myrmecophilous associations would be affected by the availability of the host plant mediated resources (food and/or shelter) to the ants and/or the lycaenids. The association of the same ant species with two sympatric lycaenids, each utilizing its specific host plant, provides a very good model system to test this hypothesis. Therefore, the present study addresses the following two questions: (i) How is the association between *C. compressus* ants, each of the two sympatric lycaenids and the respective host plants, influenced by host plant phenology? (ii) Are there ultrastructural differences in the myrmecophilous organs of the two sympatric lycaenid species?

Materials and Methods

Study site and systems

The field observations were carried out in the Botanical Garden of Banaras Hindu University campus, Varanasi (25°18' N and 80°1' E, 76 m above the mean sea level) in Uttar Pradesh, India.

There were two study systems: *Camponotus compressus* - *Chilades pandava* - *Cycas revoluta* complex and *Camponotus compressus* - *Euchrysops cnejus* - *Vigna unguiculata* complex. *Cy. revoluta*, a palm-like tree with a stout trunk and a crown formed by large, evergreen and pinnate leaves (Jones, 2002), is one of the host plant of the tropical lycaenid, *Cl. pandava* commonly known as the plains cupid or cycad blue is native to southern Asia (Moore *et al.*, 2005). The young leaves are circinately coiled (Raju & Rao, 2011). The life cycle of this lycaenid is known to consist of the egg, four larval instars, the pupal stage and the adult butterfly (Raju, 2009). The caterpillars feed on the tender emerging fronds of *Cy. revoluta* plants and cause extensive damage to the leaves (Moore *et al.*, 2005; Marler, 2012; Marler & Lawrence, 2012). *Cl. pandava*, therefore has become a conspicuous and serious pest on native (Raju, 2009) and horticultural cycads (Wu *et al.*, 2010). Other host plants of *Cl. pandava* are *Bauhinia* spp., *Butea monosperma* (Lam.) Taub., *Desmodium*

dalbergiodes Roxb. and *Acacia* sp. (Robinson *et al.*, 2010; Nitin *et al.*, 2018). The natural distribution of this butterfly spans Indo-Asia, including India, Sri Lanka, Sundaland, Philippines, Taiwan (Igarashi & Fukuda, 2000), Japan, Guam, Madagascar, Mauritius, Egypt, and the United Arab Emirates (Moore *et al.*, 2005; Wu *et al.*, 2010).

V. unguiculata, commonly known as cowpea, is an annual crop plant. It bears extrafloral nectaries on the stipules of the trifoliate leaves and also at the base of the inflorescence. The plant grows to a height of about 50-60cm and the flowers are borne in the leaf axils, in clusters of two to four (Kuo & Pate, 1985). *V. unguiculata* is the host of another common lycaenid, the gram blue butterfly, *E. cnejus* that is widely distributed in India, Malayan subregion, extending to Australia and the South Sea Islands (Varshney & Peter, 2015). It has been reported on pod-bearing host plants belonging to the family Fabaceae including those belonging to the genus *Vigna*, *Butea monosperma*, *Desmodium dalbergiodes*, *Acacia* sp., *Phaseolus* sp., *Cajanus cajan* (L.) Millsp. (Robinson *et al.*, 2010). Life cycle of *E. cnejus* is known to consist of the egg stage, four larval instars, the pupal and the adult butterfly stage (Akand *et al.*, 2015).

Ant-lycaenid-host plant association

Field observations, during the growth season of the respective host plants, were carried out for 2 years, in each case. To monitor *C. compressus* - *Cl. pandava* - *Cy. revoluta* complex, observations were conducted on the cycas host plants (n = 15) from April to September, (2015 & 2016) while observations pertaining to *C. compressus* - *E. cnejus*- *V. unguiculata* complex were carried out on the cowpea plants (n = 30), from March to August (2015 & 2016).

The occurrence of ants and lycaenids on each species of host plants were recorded by the standard visual scanning method (as per the method of Agarwal & Rastogi, 2009). Each host plant was visually scanned for 5 mins (from 8:00 - 11:00 h) for the presence and activity of ants and the lycaenid caterpillars. The observations were carried out four times a month. The area in the vicinity of the plants was examined (4 times

a month) and the number of *C. compressus* satellite nests and the distance of each, if any, from the host plants were recorded.

Scanning electron microscopy

The fourth instar caterpillars (n = 5, in each case) of *Cl. pandava* and *E. cnejus* were respectively collected from the infested new leaves of cycas plants and from the cowpea plant pods. The caterpillars were prepared for scanning electron microscopy by using the method of Kumari *et al.* (2012) with minor modifications. Caterpillars were rinsed in distilled water and fixed in 2.5% glutaraldehyde in 0.1 M sodium cacodylate buffer, at pH 7.4 for 2–2.5 hours at 4°C. Following fixation, the caterpillar samples were washed in 0.1 M sodium cacodylate buffer (pH 7.4) for three times each for 1 hour at 4°C and dehydrated at 4°C with graded acetone in ascending concentrations. After absolute acetone treatment the material was kept at 37°C for 48 hours. The caterpillar samples were then attached to stubs, coated with gold using Sputter Coater (SC7620, Quorum Technologies Ltd., UK) and examined with a scanning electron microscope (EVO® LS 10 Zeiss, Germany). Results were recorded using an Intel Pentium IV D computer (Model dx2280 MT, Hp Compaq, USA).

Results

Ant-lycaenid-host plant association

As members of *C. compressus* - *Cl. pandava* - *Cy. revoluta* complex, the *Cl. pandava* caterpillars were found only on the tender, young, unfurled fronds of *Cy. revoluta*. These newly emerged fronds were recorded on the *Cy. revoluta* plants for 15-20 days only during the months of April and September, each year. The minor caste workers of *C. compressus* were recorded on the new foliage only after the occurrence of the (first and/or second instar) *Cl. pandava* caterpillars on the cycas plants (Fig. 1B).

As components of the *C. compressus* - *E. cnejus* - *V. unguiculata* complex, the minor caste worker ants visited the extrafloral nectaries of the young (pre-flowering) cowpea plants even before the occurrence of the early (first and/or second) instar caterpillars on the plants. Later, interactions of *C. compressus* with the third/

Facultative associations of two sympatric lycaenid butterflies



Figure 1: A. *Chilades pandava* butterfly on *Cycas revoluta* young leaf; B. *Camponotus compressus* worker ants tending *C. pandava* caterpillars on a cycas leaf; C. *Euchrysops cnejus* butterfly on the leaf of *Vigna unguiculata*; D. Caterpillars of *E. cnejus* on the cowpea pod.

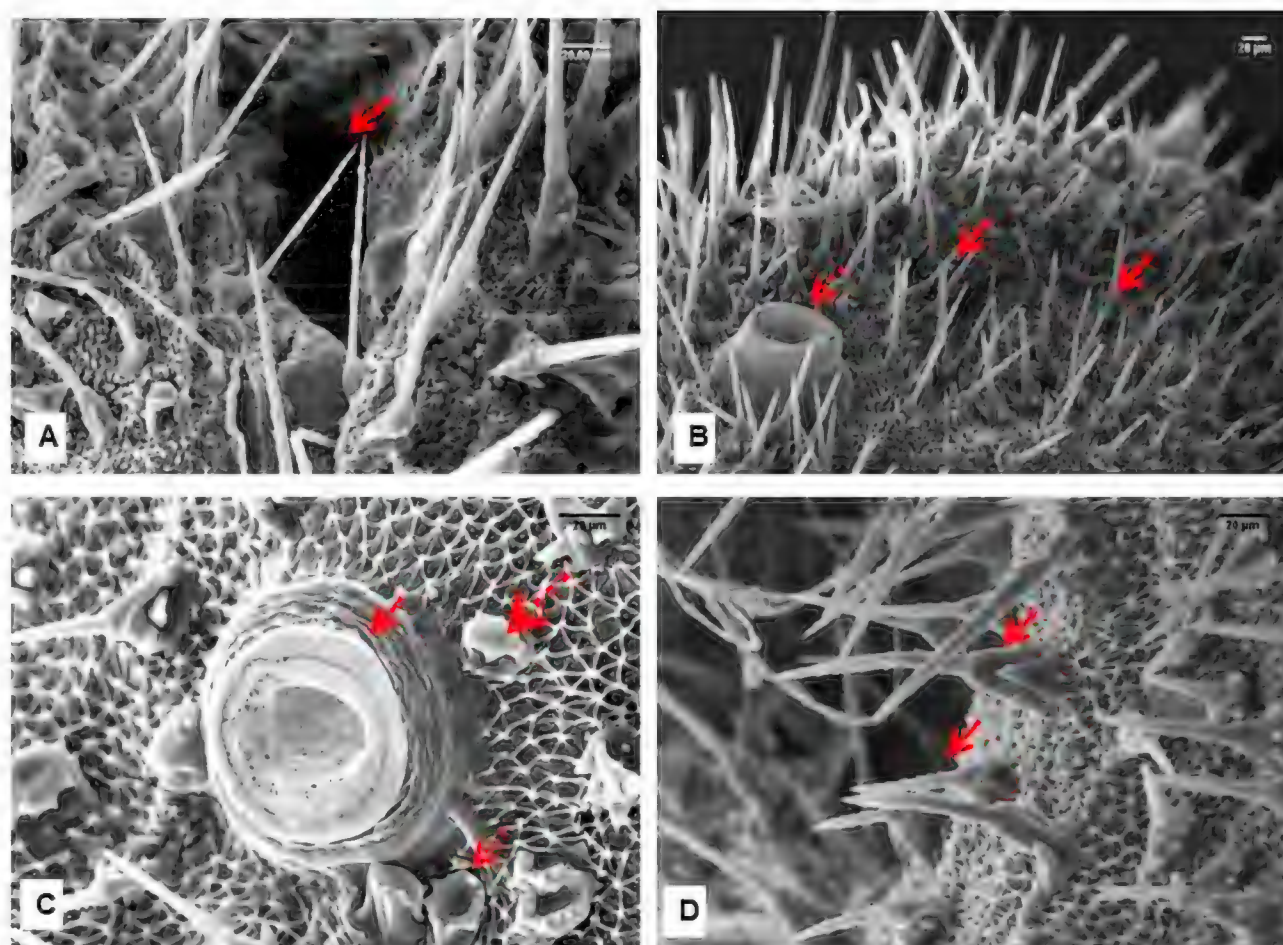


Figure 2. Scanning electron micrographs of the IV instar larva of *Chilades pandava*: A. Dorsal nectary organ (arrow); B. Retracted tentacle organ (broken arrow) surrounded by setae (arrows); C. Spiracle (arrow) surrounded by pore cupola organs (broken arrows); D. Stellate based setae (arrows) on the abdomen.

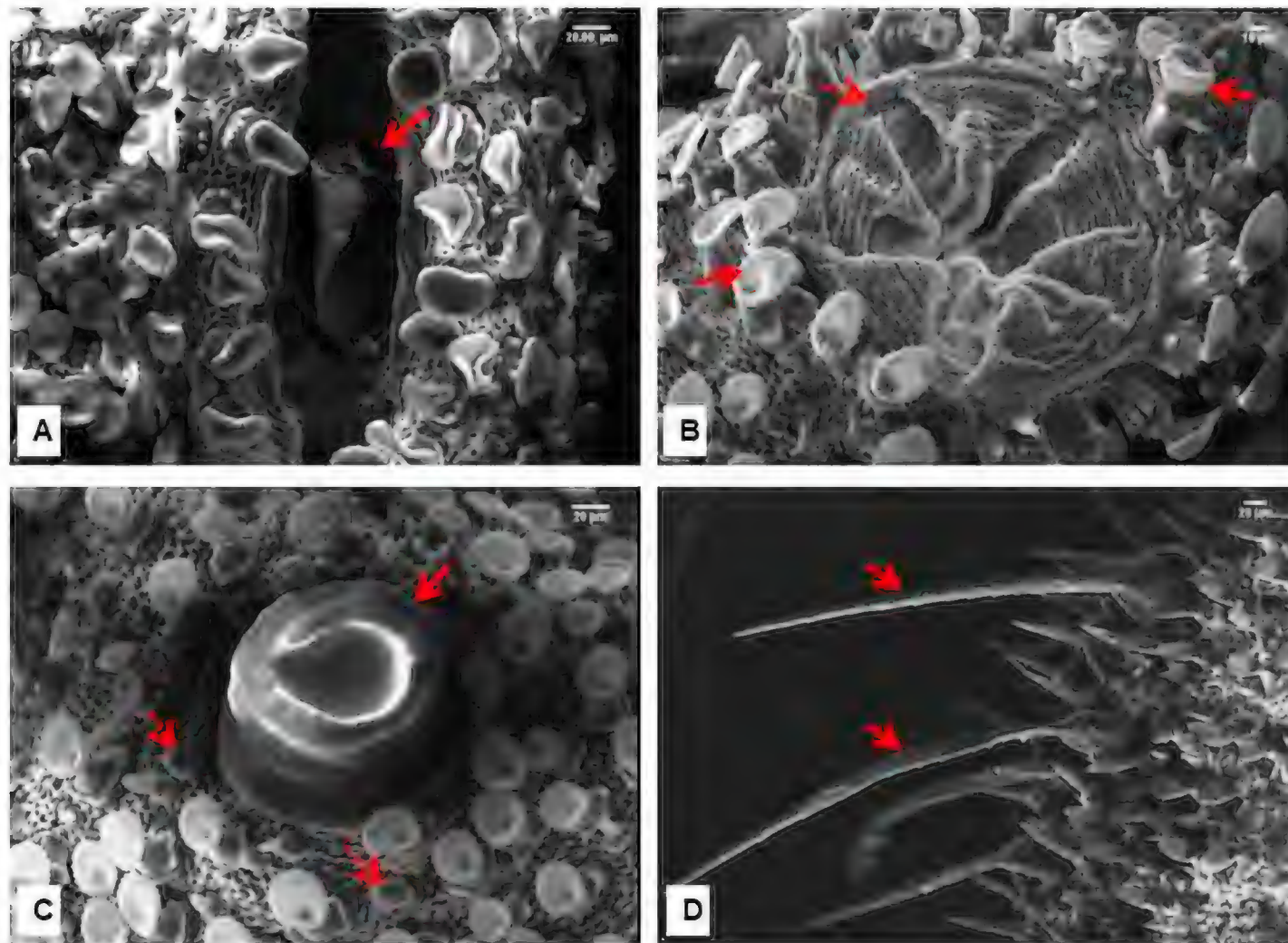


Figure 3. Scanning electron micrographs of the IV instar larva of *Euchrysops cnejus*: **A.** Dorsal nectary organ (arrow); **B.** Retracted tentacle organ (broken arrow) surrounded by disc-shaped setae (arrows); **C.** spiracle (arrow) surrounded by pore cupola organs (broken arrows); **D.** Stellate based long setae (arrows) on the abdomen.

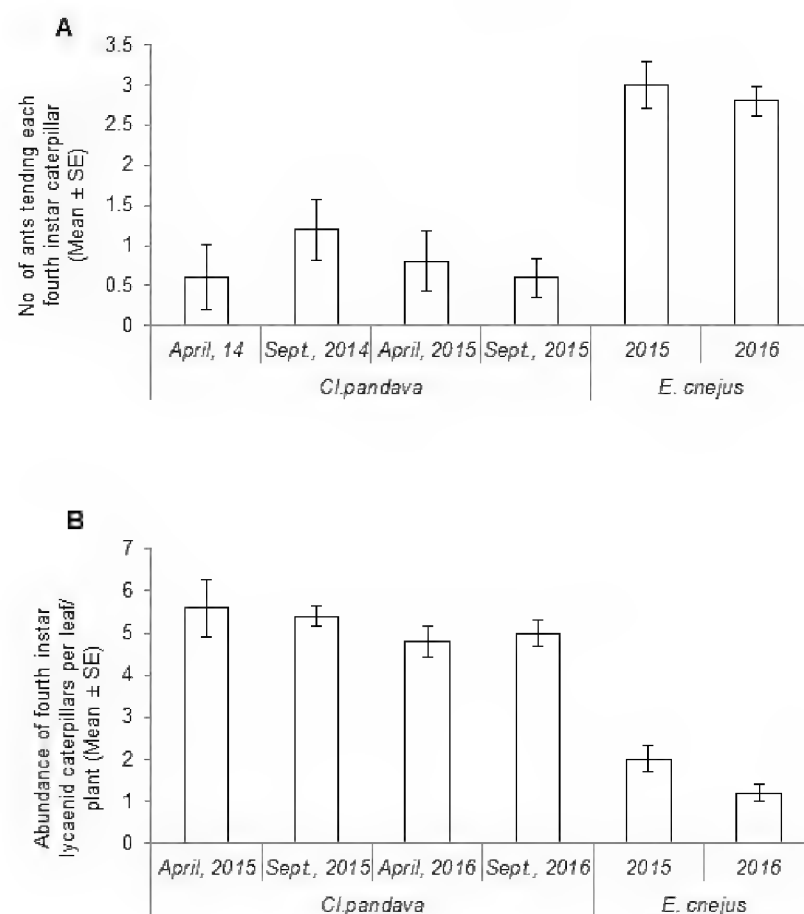


Figure 4: **A.** Number (Mean ± SE) of *Camponotus compressus* ant attendants on fourth instar caterpillars of *Chilades pandava* and *Euchrysops cnejus*; **B.** Abundance (Mean ± SE) of fourth instar lycaenid caterpillars of *Cl. pandava* per *Cycas revoluta* leaf and of *E. cnejus* per *Vigna unguiculata* plant.

Facultative associations of two sympatric lycaenid butterflies

Table 1. Field study of ant-lycaenid-host plant association between *Camponotus compressus* ants and lycaenids: *Chilades pandava* (on *Cycas revoluta*) during April & September and with *Euchrysops cnejus* (on *Vigna unguiculata*) during March-August, 2015–2016. Control (ant-excluded), Experimental (ant-included).

Parameters	<i>Cycas revoluta</i> (perennial)	<i>Vigna unguiculata</i> (annual)
First occurrence of <i>Camponotus compressus</i> on the plants	8.33 ± 0.88 days (range: 7-10 days) after emergence of new leaves	36.66 ± 4.41 days (range: 35-45 days) after plant emergence from seed
First occurrence of lycaenid larvae on the plants	5.0 ± 0.57 days (range: 4-6 days) after emergence of new leaves	55.66 ± 2.96 days (range: 50-60 days) after plant emergence from seed
Time of satellite nest occurrence within 100m² of host plant	April, 2015: 12.33 ± 1.45 days Sept., 2015: 10.33 ± 1.45 days April, 2016: 11.66 ± 1.45 days Sept., 2016: 11.66 ± 1.85 days (after emergence of new leaves)	2015: 65.33 ± 3.52 days 2016: 67.66 ± 3.84 days (after plant emergence from seed)
Number of satellite nests associated with each lycaenid-harboring host plant (Mean ± SE)	April, 2015: 0.75 ± 0.55 (range: 1-2) Sept., 2015: 0.5 ± 0.28 (range: 0-1) April, 2016: 1.0 ± 0.40 (range: 1-2) Sept., 2016: 1.0 ± 0.57 (range: 1-2)	2015: 0.50 ± 0.43 (range: 1-2) 2016: 0.62 ± 0.26 (range: 1-2)
Distance of satellite nests from each host plant (Mean ± SE)	April, 2015: 26.33 ± 13.84 cm (range: 12.5-54 cm) Sept., 2015: 24.33 ± 5.6 cm (range: 13-30 cm) April, 2016: 23.26 ± 3.93 (range: 15.4-27.2 cm) Sept., 2016: 34 ± 11.66 (range: 11.8-47 cm)	2015: 89.90 ± 42.7 cm (range: 47.2-218 cm) 2016: 66.72 ± 33.08 cm (range: 26.3-210 cm)

fourth instar *E. cnejus* caterpillar were recorded during the flowering/fruiting period of the plant (Fig. 1D). The number of ant attendants on fourth instar caterpillars was higher in case of *E. cnejus* as compared to *Cl. pandava* (Fig. 4A). Abundance of fourth instar lycaenid *Cl. pandava* caterpillars was high on *Cy. revoluta* as compared to that of *E. cnejus* on *V. unguiculata* plants (Fig. 4 B).

Satellite nests (range: 1-2) of *C. compressus* colonies were recorded at or near the base of the lycaenid caterpillar-harboring, cycas and cowpea plants (Table 1) after the arrival of the lycaenids on the respective host plants.

Scanning electron microscopy

The scanning electron microscopy of the ultrastructure of the abdomen of the fourth instar lycaenid caterpillars of *Cl. pandava* and *E.*

cnejus revealed the presence of three types of myrmecophilous organs, in each case: DNO was visible as an opening on the dorsal portion of the seventh abdominal segment (Fig. 2A, 3A), a pair of retracted TOs (Fig. 2B, 3B) were located on the eighth abdominal segment and PCOs were wart-like glandular structures distributed throughout the larval abdomen (Fig. 2C, 3C). Other observed structures included a pair of spiracles (Fig. 2C, 3C), prominently visible as round structures on each of the seventh and eighth abdominal segments and presence of setae on the abdomen (Fig. 2D, 3D). Only a single type of long and stellate base setae (Fig. 2D) were recorded on the body of *Cl. pandava* larvae while two types of setae: stellate based short disc-like setae (Fig. 3B) and long tactile setae (Fig. 3D) were present on the body of *E. cnejus* larvae.

Discussion

The results of the field study of the two types of ant-lycaenid-host plant complexes indicate facultative associations in both the cases under study, involving spatiotemporal synchronization between the lycaenid, their respective host plants and *C. compressus* ants. It has been reported that *Cl. pandava* and *E. cnejus* facultatively associates with *Camponotus* sp. as well as other ant species (Eastwood & Fraser, 1999; Heath & Claassens, 2003). The results also indicate that the ant-lycaenid-host plant associations are strongly influenced by two important host plant related factors, the presence and/or absence of the: i. food for the ants, and ii. food and shelter for the lycaenid caterpillars.

Cl. pandava caterpillars were recorded on the cycas plants much before the ant visits were recorded on the plants. The association of *Cl. pandava* was found to be more strongly synchronized with its host plant phenology and relatively less strongly with the late-arriving *C. compressus* ant partners since the host plant offered no food at all for the ant partner. The tender tightly curled up fronds of the cycas apparently provided not only food but also shelter to the early stages of *Cl. pandava* caterpillars. The vulnerable early instar caterpillars remained concealed within the young, circinately coiled leaflets of the fronds. However, the host plant phenology imposed a constraint on the lycaenid since there was only a short window period (range: 15-20 days) in the availability of these resources to the *Cl. pandava* juveniles, during the months of April and September of each year. Thus, there was a fine-tuned synchronization of the larval developmental period with the bi-annual emergence of young fronds. The late instar larvae were exposed to their enemies later when the leaves gradually matured, hardened in texture and unfurled. At this stage the third and/or fourth larvae were tended by the late-visiting *C. compressus* ants.

In contrast, the presence of 2 types of extrafloral nectaries in *V. unguiculata* consistently provided food to the worker ants and thereby ensured their presence on the plants, even before the arrival of the lycaenid caterpillars. While the seeds of the developing pods of the cowpea plants served as food, the

pods provided shelter to the early vulnerable instars of *E. cnejus*. The lycaenid caterpillars are reportedly susceptible to parasitoids (Gupta *et al.*, 2014). Therefore, the developing larval instars could obtain an enemy-free space within the pods and on emerging out from the pods could obtain protection by the already arrived ant guards which were present in close vicinity, feeding at the plant provided extrafloral nectaries.

Various studies have reported that lycaenid caterpillars occur predominantly on the plants where ants are present (Seufert & Fiedler, 1996; Kaminski *et al.*, 2012). Evolution towards myrmecophily in Lycaenidae is correlated with the utilization of nitrogen-rich host plants as nitrogen can enhance their overall fitness and survival and the amount of nitrogen required to complete an insect's life cycle may vary greatly among species (Pellissier *et al.*, 2012). Cycas plants associate with nitrogen fixing cyanobacteria within specialized roots enabling the plants to maintain a homeostasis of leaf nitrogen concentration throughout heterogeneous soil conditions and herbivory pressures (Marler & Dongol, 2016). We suggest that the nitrogen concentrations and texture of the cycas young leaves may be optimal for the plant-feeding larval stages as compared to older leaves. Moreover the coiled leaflets conceal the vulnerable early instars and account for the preference of the larvae for freshly emerged fronds. The cowpea seeds are also reported to have high protein content (Gupta *et al.*, 2014).

The field observations revealed that the *C. compressus* colonies exhibit similar behavioural responses in terms of establishment of satellite nests in the vicinity of the lycaenid-harboursing host plants in both the cases thereby revealing the propensity of attending ants to construct temporary nests in the vicinity of lycaenid-harboursing plants. The satellite nest construction occurred after the arrival of the lycaenids on the plants in both the cases. *C. compressus* being a polydomous ant species (Kumari *et al.*, 2016) apparently utilizes this strategy to maximize its access to the highly attractive, DNO secretion produced by the tended caterpillars of both the lycaenid species.

This is the first study of the ultrastructure of the myrmecophilous organs of

Cl. pandava and *E. cnejus*. The SEM observations revealed similarities in the three basic myrmecophilous organs, (DNO, PCOs and TOs) of the last instar larvae of each of the two sympatric lycaenid butterfly species involved in food for defence association with the same species of carpenter ant, *C. compressus*. Evidently, all the three important myrmecophilous organs have been conserved in these two lycaenid species even though they belong to different genera. These basic myrmecophilous organs are needed to pacify ant workers to facilitate ant attendance and association with the lycaenids (Fiedler, 1991; Pierce *et al.*, 2002; Kaminski *et al.*, 2012).

Our results revealed the presence of two morphologically distinct types of setae. The stellate based short disc-like setae along with long setae were located on the abdomen of *E. cnejus* while only a single type of long-stellate based setae were distributed throughout the abdomen of *Cl. pandava* caterpillars. Setae occur on larvae of many members of the Lycaenidae (Ballmer & Pratt, 1988). The setae vary in shape, density and distribution among lycaenid species (Kitching & Luke, 1985; Ballmer & Pratt, 1991). Earlier studies have shown that the modified setae are involved in larval myrmecophily and may be of various shapes such as club-shaped (Fiedler, 1991; Tautz & Fiedler, 1992), dome shaped (Kitching & Luke, 1985), mushroom-like or dendritic (Tautz & Fiedler, 1992).

The perforated pore-like structures, the PCOs were distributed on the abdomen and more number of PCOs were recorded around the DNO and TOs of both the lycaenid species. It has been reported that the PCOs are universally present on majority of lycaenid larvae with tightly clustered distribution around DNO and TOs (Kitching & Luke, 1985; Fiedler, 1991; Pierce *et al.*, 2002; Kaminski & Freitas, 2010). The PCOs are found to exude ant attractant or appeasement substances that suggestedly contain polypeptides and/or free amino acids (Hojo *et al.*, 2014). These are said to be the earliest myrmecophilous adaptations and help in avoiding ant attack (Fiedler *et al.*, 1996; Pierce *et al.*, 2002).

SEM studies revealed DNO as an opening like structure located on the dorsal

surface of the seventh abdominal segment of the larva, in each species. This organ was found to be surrounded with setae and a large number of PCOs. The presence of DNO is widely observed in lycaenid larvae and is probably a primitive condition. Our results support earlier studies (Pierce *et al.*, 2002; Hojo *et al.*, 2008; Dupont *et al.*, 2016) indicating its important fundamental role in ant-lycaenid association. Droplets of an aqueous solution containing sugars and amino acids are known to be secreted by the DNO when the larvae are stimulated by the antennation of ants (Wada *et al.*, 2001; Daniels *et al.*, 2005). Recent work on the Japanese species, *Narathura japonica* Murray, 1875, has shown that the DNO secretions can also manipulate attendant ant behaviour via the dopaminergic pathway (Hojo *et al.*, 2015).

Our study also revealed the presence of the retracted TOs on the eighth abdominal segment as reported in the previous studies (Pierce *et al.*, 2002; Hojo *et al.*, 2008; Dupont *et al.*, 2016). These tentacles are everted when palpated by ants, showing a corona of spiny setae. The TOs of both the lycaenid species were similar to the TOs reported from various other lycaenid species such as *Hemiargus hanno* Stoll, 1790, *Parrhasius polibetes* Stoll, 1782 and *Liphyra brassolis* Westwood, 1864 (Kitching & Luke, 1985; Duarte *et al.*, 2001; Kaminski *et al.*, 2012; Dupont *et al.*, 2016). Some studies have proposed that the TOs may release a volatile substance that attract and alert attendant ants (Axén *et al.*, 1996). However, a recent study by Gnatzy *et al.* (2017) has shown that the tentacle hairs are typical insect mechanoreceptors, each innervated by a small bipolar sensory cell with a tubular body in the tip of the outer dendritic segment and no glandular structures were found on TOs.

All the three myrmecophilous organs studied are thus exocrine in nature and are found to secrete substances that entice, alarm, appease, feed, and/or manipulate attending ants (Pierce *et al.*, 2002; Hojo *et al.*, 2015). These secretions are said to be responsible for the suppression of ant aggression, maintenance of standing-guard, and ant-mediated defensive measures. Ant workers are found to provide an enemy-free space for the vulnerable caterpillars thereby aiding in larval defence against predators,

parasites and parasitoids (Atsatt, 1981; Fiedler *et al.*, 1996; Gupta *et al.*, 2014).

The plant-visiting *C. compressus* minor caste ants apparently contribute facultatively towards enhancement of the survival of the lycaenid larvae in both the species. It is well established that ant association has exerted a strong selection pressure on lycaenid larval morphology (Pierce *et al.*, 2002). Long and densely distributed setae form flexible armour and reportedly are adaptations of the facultative lycaenid species to avoid predation and resist attack by their host ants (Dupont *et al.*, 2016). The differences in the type of larval setae of the two species appear to be adaptations for entraining ant attendance and may indicate the behavioural shifts and differences in the larval survival strategies, although more research is needed to elucidate the role of the two types of setae. The species specific differences in the host plant phenology and differential contribution of resources to the lycaenid and its ant partners influences the synchronization of lycaenid larval developmental period on the plant with its ant body guards. The host plant attributes appear to be significant in facilitation of food and shelter to the vulnerable lycaenid stages and in making the association more strongly ant-dependent (tritrophic) in case of ant-*E. cnejus*-cowpea host plant complex as compared to that between *C. pandava* and the ants. The study thus highlights the differences in the selection pressures on the two sympatric lycaenid species associated with the same ant species.

Acknowledgements

The authors wish to thank Prof. N.K. Dubey, Department of Botany, Banaras Hindu University, Varanasi, India, for kindly facilitating the field studies in the Botanical garden of Banaras Hindu University. We are grateful for the funding support from the Department of Science and Technology-Fund for Improvement of Science and Technology, India, for the Scanning Electron Microscope facility to the Department of Zoology, Banaras Hindu University.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Funding support to Priya Aradhya Ekka (09/013 (0536)/ 2014-EMR-I) from the Council of Scientific & Industrial Research, New Delhi, India and to Sudha Kumari (R. Dev/IX Sch/RF CAS-Zoology-14740) from the Centre of Advanced Study, University Grants Commission, India is gratefully acknowledged.

References

- Agarwal, V.M. and Rastogi, N. 2009. Spatiotemporal dynamics and plant-part preference patterns of the plant-visiting ants and the insect herbivores of sponge gourd plants. *Journal of Asia Pacific Entomology* 12: 57–66.
- Agarwal, V.M. and Rastogi, N. 2010. Ants as dominant insect visitors of the extrafloral nectaries of sponge gourd plant, *Luffa cylindrical* (L.) (Cucurbitaceae). *Asian Myrmecology* 3: 45–54.
- Akand, S., Bashir, M.A. and Khan, H.R. 2015. Biology of gram blue butterfly, *Euchrysops cnejus* (Fabricius) (Lycaenidae: Lepidoptera) and its relationship with the phenology of host-plant (*Vigna unguiculata*: Fabaceae). *Journal of Bangladesh Academy of Sciences* 39: 241–248.
- Als, T.D., Nash, D.R. and Boomsma, J.J. 2002. Geographical variation in host-ant specificity of the parasitic butterfly *Maculinea alcon* in Denmark. *Ecological Entomology* 27: 403–414.
- Atsatt, P.R. 1981. Lycaenid butterflies and ants: selection for enemy-free space. *The American Naturalist* 118: 638–654.
- Axén, A.H., Leimar, O. and Hoffman, V. 1996. Signalling in a mutualistic interaction. *Animal Behaviour* 52: 321–333.
- Bächtold, A., Alves-Silva, E., Kaminski, L.A. and Del-Claro, K. 2014. The role of tending ants in host plant selection and egg parasitism of two facultative myrmecophilous butterflies. *Naturwissenschaften* 101: 913–919.
- Ballmer, G.R. and Pratt, G.F. 1988. A survey of the last instar larvae of the Lycaenidae of

- California. The Journal of research on the Lepidoptera 27: 1–81.
- Ballmer, G.R. and Pratt, G.F. 1991. Quantification of ant attendance (myrmecophily) of lycaenid larvae. The Journal of research on the Lepidoptera 30: 95–112.
- Bharti, H., Guénard, B., Bharti, M. and Economo, E.P. 2016. An updated checklist of the ants of India with their specific distributions in Indian states (Hymenoptera, Formicidae). Zookeys 551: 1–83.
- Daniels, H., Gottsberger, G. and Fiedler, K. 2005. Nutrient composition of larval nectar secretions from three species of myrmecophilous butterflies. Journal of Chemical Ecology 31: 2805–2821.
- Duarte, M., Almeida, G.L., Casagrande, M.M. and Mielke, O.H.H. 2001. Notes on the last instar and pupa of *Hemiargus hanno* (Stoll) (Lepidoptera, Lycaenidae, Polyommatainae). Revista Brasileira de Zoologia 18: 1097–1105.
- Dupont, S.T., Zemeitat, D.S. and Lohman, D.J. 2016. The setae of parasitic *Liphyra brassolis* butterfly larvae form a flexible armour for resisting attack by their ant hosts (Lycaenidae: Lepidoptera). Biological Journal of the Linnean Society 117: 607–619.
- Eastwood, R. and Fraser, A.M. 1999. Associations between lycaenid butterflies and ants in Australia. Australian Journal of Ecology 24: 503–537.
- Ekka, P.A. and Rastogi, N. 2017. Satellite nest architecture and demography of the plant-visiting ant, *Camponotus compressus* (Fabricius). Entomon 42: 239–244.
- Fiedler, K. 1991. Systematic, evolutionary, and ecological implications of myrmecophily within the Lycaenidae (Insecta: Lepidoptera: Papilionoidea). Bonner Zoologische Monographien 31: 1–210.
- Fiedler, K. 1996. Host-plant relationships of lycaenid butterflies: large-scale patterns, interactions with plant chemistry, and mutualism with ants. Entomologia Experimentalis et Applicata 80: 259–267.
- Fiedler, K. 2012. The host genera of ant-parasitic lycaenidae butterflies: a review. Psyche Article ID 153975.
- Fiedler, K., Hölldobler, B. and Seufert, P. 1996. Butterflies and ants: the communicative domain. Experientia 52: 14–24.
- Fiedler, K. and Maschwitz, U. 1988. Functional analysis of the myrmecophilous relationships between ants (Hymenoptera: Formicidae) and lycaenids (Lepidoptera: Lycaenidae) II. lycaenid larvae as trophobiotic partners of ants: a quantitative approach. Oecologia 75: 204–206.
- Gnatzy, W., Jatho, M., Kleinteich, T., Gorb, S. and Hustert, R. 2017. The eversible tentacle organs of *Polyommatus* caterpillars (Lepidoptera, Lycaenidae): Morphology, fine structure, sensory supply and functional aspects. Arthropod Structure & Development 46(6): 788–804. doi: 10.1016/j.asd.2017.10.003.
- Gupta, A., Churi, P.V., Sengupta, A. and Mhatre, S. 2014. Lycaenidae parasitoids from peninsular India with description of four new species of microgastrine wasps (Hymenoptera: Braconidae) along with new insights on host relationships. Zootaxa 3827: 439–470.
- Gupta, P., Singh, R., Malhotra, S., Boora, K.S. and Singal, H.R. 2014. Cowpea [*Vigna unguiculata* (L.) Walp.] seed proteins: heterogeneity in total proteins and protein fractions. Legume Research 37: 62–67.
- Hansen, L.D. and Akre, R.D. 1985. Biology of carpenter ants in Washington State (Hymenoptera: Formicidae: *Camponotus*). Melanderia 43: 1–62.
- Heath, A. and Claassens, A.J.M. 2003. Ant-association among southern African Lycaenidae. Journal of the Lepidopterists' Society 57: 1–16.
- Hojo, M.K., Pierce, N.E. and Tsuji, K. 2015. Lycaenid caterpillar secretions manipulate attendant ant behavior. Current Biology 25: 2260–2264.
- Hojo, M.K., Wada-Katsumata, A., Akino, T., Yamaguchi, S., Ozaki, M. and Yamaoka, R. 2009. Chemical disguise as particular caste of host ants in the ant inquiline parasite *Niphandia fusca* (Lepidoptera: Lycaenidae). Proceedings of the Royal Society of London B 276: 551–558.
- Hojo, M.K., Wada-Katsumata, A., Yamaguchi, S., Ozaki, M. and Yamaoka, R. 2008.

- Gustatory synergism in ants mediates a species-specific symbiosis with lycaenid butterflies. *The Journal of Comparative Physiology* 194: 1043–1052.
- Hojo, M.K., Yamaguchi, S., Akino, T. and Yamaoka, R. 2014. Adoption of lycaenid *Niphandia fusca* (Lepidoptera: Lycaenidae) caterpillars by the host ant *Camponotus japonicas* (Hymenoptera: Formicidae). *Entomological Science* 17: 59–65.
- Igarashi, S. and Fukuda, H. 2000. The life histories of Asian butterflies. Vol 2. Tokyo: Tokai University Press, 742pp.
- Jones, D.L. 2002. *Cycads of the World: Ancient Plants in Today's Landscape*, 2nd ed. Washington, D.C.: Smithsonian Inst. Press, 1–456.
- Kaminski, L.A. and Freitas, A.V.L. 2010. Natural history and morphology of immature stages of the butterfly *Allosmaitia strophius* (Godart) (Lepidoptera: Lycaenidae) on flower buds of Malpighiaceae. *Studies on Neotropical Fauna and Environment* 45: 11–19.
- Kaminski, L.A. and Rodrigues, D. 2011. Species-specific levels of ant attendance mediate performance costs in a facultative myrmecophilous. *Physiological Entomology* 36: 208–214.
- Kaminski, L.A., Rodrigues, D. and Freitas, A.V.L. 2012. Immature stages of *Parrhasius polibetes* (Lepidoptera: Lycaenidae): host plants, tending ants, natural enemies and morphology. *Journal of Natural History* 46: 645–667.
- Kitching, R.L. and Luke, B. 1985. The myrmecophilous organs of the larvae of some British Lycaenidae (Lepidoptera): a comparative study. *Journal of Natural History* 19: 259–276.
- Kumari, U., Mittal, S. and Mittal, A.K. 2012. Surface ultrastructure of the gill filaments and the secondary lamellae of the catfish, *Rita rita* and the carp, *Cirrhinus mrigala*. *Microscopy Research and Technique* 75: 433–440.
- Kumari, S., Singh, H. and Rastogi, N. 2016. Influence of the sugar-loving ant, *Camponotus compressus* (Fabricius, 1787) on soil physico-chemical characteristics. *Halteres* 7: 163–174.
- Kuo, J. and Pate, J.S. 1985. The extrafloral nectaries of cowpea (*Vigna unguiculata* (L.) Walp): I. Morphology, anatomy and fine structure. *Planta* 166: 15–27.
- Leimar, O. and Axén, A.H. 1993. Strategic behaviour in an interspecific mutualism: interaction between lycaenidae and ants. *Animal Behaviour* 46: 1177–1182.
- Marler, T.E. 2012. *Chilades pandava* damage among 85 *Cycas* species in a common garden setting. *Horticultural Science* 47: 1832–1836.
- Marler, T.E. and Dongol, N. 2016. Three invasive insects alter *Cycas micronesica* leaf chemistry and predict changes in biogeochemical cycling. *Commun Integr Biol*. 9: e1208324.
- Marler, T.E. and Lawrence, J.H. 2012. Demography of *Cycas micronesica* on Guam following introduction of the armoured scale *Aulacaspis yasumatsui*. *Journal of Tropical Ecology* 28: 233–242.
- Martins, D.J., Collins, S.C., Congdon, C. and Pierce N.E. 2013. Association between the African lycaenid, *Anthene usamba*, and an obligate acacia ant, *Crematogaster mimosae*. *Biological Journal of the Linnean Society* 109: 302–312.
- Moore, A., Marler, T., Miller, R.H. and Muniappan, R. 2005. Biological control of *Cycad aulacaspis* scale on Guam. *The Cycad Newsletter* 28: 6–8.
- Nitin, R., Balakrishnan, V.C., Churi, P.V., Kalesh, S., Prakash, S., and Kunte, K. 2018. Larval host plants of the butterflies of the Western Ghats, India. *Journal of the Threatened Taxa* 10: 11495–11550.
- Pellissier, L., Rasmann, S., Litsios, G., Fiedler, K., Dubuis, A., Pottier, J. and Guisan, A. 2012. High host-plant nitrogen content: a prerequisite for the evolution of ant-caterpillar mutualism? *Journal of Evolutionary Biology* 25: 1658–1668.
- Pierce, N.E., Braby, M.F., Heath, A., Lohman, D.J., Mathew, J., Rand, D.B. and Travassos, M.A. 2002. The ecology and evolution of ant association in the Lycaenidae (Lepidoptera). *Annual Review of Entomology* 47: 733–771.
- Raju, A.J.S. 2009. Nesting behaviour of the Baya Weaver bird, *Ploceus philippinus*

- (Ploceidae) and the life-cycle of the Plains Cupid butterfly, *Chilades pandava* (Lycaenidae) with the red-listed *Cycas sphaerica* and *C. beddomei* (Cycadaceae). *Journal of Threatened Taxa* 1: 429–433.
- Raju, A.J.S. and Rao, N.G. 2011. Taxonomic aspects and coning ecology of *Cycas circinalis* L. (Cycadales: Cycadaceae), a threatened species of India. *Journal of Threatened Taxa* 3: 1425–1431.
- Robinson, G.S., Ackery, P.R., Kitching, I.J., Beccaloni, G.W. and Hernandez, L.M. 2010. HOSTS – A Database of the World's Lepidopteran Hostplants. Natural History Museum, London, UK. <http://www.nhm.ac.uk/hosts>. Accessed on: 22 March 2019.
- Saarinen, E.V. and Daniels, J.C. 2006. Miami blue butterfly larvae (Lepidoptera: Lycaenidae) and ants (Hymenoptera: Formicidae): New information on the symbionts of an endangered taxon. *Florida Entomologist* 89: 69–74.
- Seufert, P. and Fiedler, K. 1996. The influence of ants on patterns of colonization and establishment within a set of coexisting lycaenid butterflies in a south-east Asian tropical rain forest. *Oecologia* 106: 127–136.
- Steiner, F.M., Sielezniew, M., Schlick-Steiner, B.C., Höttinger, H., Stankiewicz, A. and Górnicki, A. 2003. Host specificity revisited: new data on *Myrmica* host ants of the lycaenid butterfly *Maculinea rebeli*. *Journal of Insect Conservation* 7: 1–6.
- Tautz, J. and Fiedler, K. 1992. Mechanoreceptive properties of caterpillar hairs involved in mediation of butterfly-ant symbioses. *Naturwissenschaften* 79: 561–563.
- Tiple, A.D., Khurad, A.M. and Dennis, R.L.H. 2011. Butterfly larval host plant use in a tropical urban context: Life history associations, herbivory, and landscape factors. *Journal of Insect Science* 11: 65.
- Trager, M.D. and Daniels, J.C. 2009. Ant tending of Miami blue butterfly larvae (Lepidoptera: Lycaenidae): partner diversity and effects on larval performance. *Florida Entomologist* 92: 474–482.
- Varshney, R.K. 1997. Index *Rhopalocera indica* Part III. Genera of Butterflies from India and neighbouring countries (Lepidoptera: (C) Lycaenidae). *Oriental Insects* 31: 88–138.
- Varshney, R.K. and Peter, S. 2015. A synoptic catalogue of the butterflies of India. New Delhi: Butterfly Research Centre, Bhimtal and Indivov Publishing, 143 pp.
- Wada, A., Isobe, Y., Yamaguchi, S., Yamaoka, R. and Ozaki, M. 2001. Taste-enhancing effects of glycine on the sweetness of glucose: a gustatory aspect of symbiosis between the ant, *Camponotus japonicas* and the larvae of the lycaenid butterfly, *Niphandia fusca*. *Chemical Senses* 26: 983–992.
- Wu, L.W., Yen, S.H., Lees, D.C. and Hsu, Y.F. 2010. Elucidating genetic signatures of native and introduced populations of the Cycad Blue, *Chilades pandava* to Taiwan: a threat both to Sago Palm and to native *Cycas* populations worldwide. *Biological Invasions* 12: 2649–2669.

Effect of the invasive phanerophytes and associated aphids on the ant (Hymenoptera, Formicidae) assemblages

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Abstract

In Kyiv and the Kyiv region (Ukraine) during 2015-2017, 47 species of aphids (Aphididae) were found on 18 native species of plants-phanerophytes and for 9 invasive plant species, 14 aphid species were found. Native species of plants-phanerophytes were visited by 19 species of ants (Formicidae) and invasive plant species by 16 species of ants. Only one aphid species (*Aphis craccivora* Koch) found on invasive plant species was invasive. Most species of invasive phanerophytes are not very attractive for ants, since they are practically not populated by aphids (*Acer negundo*, *Amorpha fruticosa*). Some tree species are inhabited by aphids only at the beginning of their life cycle (*Padus serotina*). Only some species of invasive plants (*Quercus rubra*, *Salix fragilis*) can be infested with aphids throughout their life cycle, and accordingly, are visited by ants.

Keywords: *Aphididae, invasive species, Formicidae, phanerophytes*

Received: 1 January 2020; Revised: 12 October 2020; Online: 13 November 2020

Introduction

Ever-increasing plant and animal invasions are a biological process that accompanies the on-going globalization. Alien species that control new areas often exert a spectacular, sometimes catastrophic impact not only on related individual native species, but also on local biodiversity, and thus they change the structure and functioning of plant and animal communities, biocoenoses and entire ecosystems. From among plant invasions and their ecological effects, the most intensely studied and best known are those of herbaceous species. Densely covering often large areas, such plants out-compete native herbs and, changing habitat conditions (soil properties, microclimate), radically and in many aspects affect local animal communities. Herb plant species, highly invasive in Europe, are e.g. goldenrods (*Solidago* spp.) and balsams (*Impatiens* spp.), and the animals tested for their impact were, among others, ants (Lenda *et al.*, 2013; Grześ *et al.*, 2018; Trigos-Peral *et al.*, 2018).

Invasive woody plants, i.e. phanerophytes according to Raunkiær's (1905)

classification, also play an important role in ecosystems. In the temperate zone phanerophytes are practically trees and shrubs. In the nature of things, their invasive species constitute both potential and actual threat to forestry. So the economic aspect of their impact is examined as for example in the case of the northern red oak *Quercus rubra* (Chmura, 2013) or the black cherry *Prunus serotina* (Aerts *et al.*, 2017), or the socio-economic balance of profits and losses resulting from the invasion is considered, as for the black locust *Robinia pseudoacacia* (Vitková *et al.*, 2017). Their possible effects on the animal part of biocoenosis cause far less interest.

Alien woody plants intentionally introduced into new areas for horticulture and forestry often for centuries were not considered to be dangerous invasive species. However, so far only 0.5–0.7% of the world's phanerophyte species revealed their invasive potential outside their natural range, rapidly starting spontaneous spread there, and hence gained economic and ecological importance

(Richardson and Rejmánek, 2011). Of the 622 world woody plant species recognized as invasive, 107 species occur in Europe (Richardson and Rejmánek, 2011). Seven of the latter are on a list of the '100 of the Worst' invasive species (both plants and animals) in Europe (Roy *et al.*, 2010) and 15 ones are on the similar list of the 149 invaders of Europe (Nentwig *et al.*, 2017).

The nature of vegetation significantly affecting habitat and environmental conditions determines the composition and structure of local zoocoenoses in all layers of the ecosystem – from soil to the tree crowns. In all of these layers, ants live, constituting practically in all terrestrial habitats a numerically and ecologically dominating group of the invertebrate mesofauna (Hölldobler and Wilson 1990; Wilson 1990). Relationships between plants and ants are close and multifaceted – including indirect and direct trophic connections. The vast majority of ants are pantophages: as predators they hunt for various phytophages, as melitophages they feed on plant juice, nectar, pollen and, above all, honeydew of homopterans; some also eat seeds. In the context of the present paper, the most important are the trophobiosis of ants with aphids as parasites of trees and shrubs. It can therefore be assumed that the change in vegetation associated with the presence of invasive species should trigger noticeable changes in the local myrmecofauna. The studies about the attractiveness of invasive plants for ants are single (Stukalyuk *et al.*, 2019) and most often cover the effect of invasion of single plant species on ant assemblages (Weiss *et al.*, 2005; Lenda *et al.*, 2013; Myczko *et al.*, 2018). In this study, we made an attempt to compare among themselves invasive plant species with native ones, to find out the reasons for their attractiveness or unattractiveness for ants.

The aim of the study was to verify this supposition by comparing ant assemblages in woods composed of native tree and shrub species with those more or less wooded areas with different share and composition of invasive phanerophytes. To our knowledge, research in this field has not been carried out yet.

The studied region (Kyiv region) can be a convenient model territory. Here there are all the main types of habitats characteristic of Europe - deciduous and coniferous forests and

other habitats considered in our work. Therefore, the patterns obtained by us on the model territory can be extended to vast territories with the same types of habitats. Invasive plants attractive to ants will remain so in similar habitats, and vice versa.

Materials and Methods

Study sites

The research was conducted in the years 2015–2017 in the periods from June to August in the urban greenery of Kyiv and in extra-urban environments in the Kyiv region, Ukraine. Physiographically, Kyiv is located on a border of two ecological zones: the European mixed forest zone and the forest-steppe zone (Popov *et al.*, 1968; Didukh and Aloschkina, 2012). Hence, the vegetation of the region is very rich and diverse; it represents several phytosociological classes: Pulsatilla-Pinetea, Quercetea roburi-petrea, Querco-Fagetea, Salicetea alba, Alnetea glutinosae (forest vegetation), Festuco-Brometea (steppes), Molinio-Arrhenatheretea, Koelerio-Corynephoretea (meadow vegetation), Phragmito-Magno-Caricetea, Lemnetea, Potametea (aquatic and bog vegetation) and others (Didukh and Aloschkina, 2012). There are many urban and natural parks, gardens, botanical gardens, etc. in the city, and nature conservation areas in the city environs. Altogether, the research covered 22 study sites: 18 within the city limits and four outside the city (Fig. 1). Some sites represented more than one habitat category.

Habitat classification

Based on the classification of the European Nature Information System (see EUNIS database) the sites studied represented nine EUNIS habitat categories:

1. Category G1.A162: Mixed lime-oak-hornbeam forests (association Tilio-Carpinetum; study sites 1, 2 and 6). This forest association developed in Central and Eastern Europe (Poland, Lithuania, Belarus, Ukraine, Russia) in regions of continental climate within the range of *Carpinus betulus*, east of the range of *Fagus sylvatica*. Besides from *C. betulus* the association include *Quercus petraea*, *Quercus robur*, *Tilia cordata*, *Acer platanoides*, *Fraxinus excelsior* and some possible other tree species (for more details see Protopopova *et al.*, 2014).

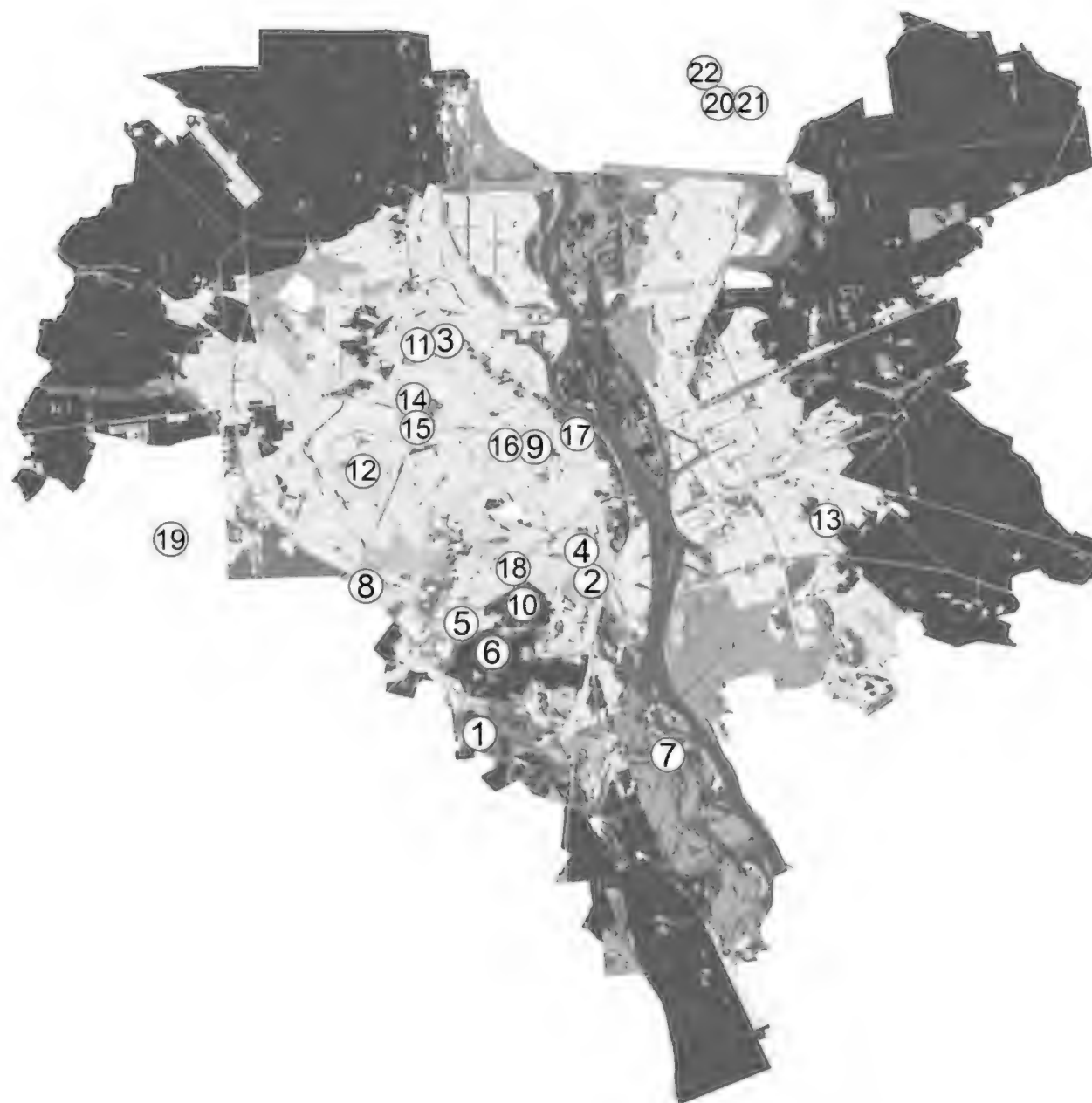


Figure 1. Kyiv in its administrative boundaries and location of study sites within and outside the city: **1.** Park of landscape garden art «Feofania»; **2.** regional landscape park «Lysa Hora» (natural park); **3.** natural landmark Kirillov Gai (natural park area); **4.** Sovskie Ponds valley (or lowland maybe better)(natural park area); **5.** Expocenter of Ukraine (a park area); **6.** Goloseyevsky Forest (a forest nature reserve); **7.** Zhukov Island (forest and meadow nature reserve); **8.** Ring Road (tree planting or lines of trees); **9.** T. G. Shevchenko Park (park area); **10.** Goloseyevsky Park (natural park area); **11.** Babi Yar Park (park area); **12.** Vidradny Park (park area); **13.** Park of Partisan Glory (park area); **14.** A. S. Pushkin Park (park area); **15.** Kyiv Polytechnic Institute (park area); **16.** A. V. Fomin Botanical Garden; **17.** Mariinsky Park (park area); **18.** street and yard greenery of the Goloseyevsky district of Kyiv (several plots close to each other); **19.** environs of the village Sofieivska Borshchagivka (Kyiv-Svyatoshinsky district); **20.** environs of the village Litky (Brovarskoy district); **21.** National natural reserve «Zalissya»; **22.** Lyubychiv island (natural territory, without park status). Gray scale: light gray – zone of high-density housing; medium gray – zone of urban and natural parks; dark gray – forest areas.

In the forests studied, the 1st layer (overstory layer) was formed by *Quercus robur* (in brackets, the numbers of trees/shrubs examined) (221), the 2nd layer (canopy layer) by *Acer platanoides* (195), *Carpinus betulus* (165) and *Fraxinus excelsior* (58), and the 3rd layer (understory) by *Euonymus verrucosus* (50), saplings of *Ulmus glabra* (90) and *A. platanoides* (210) on lighted places, and shrubs of *Sambucus nigra* (30) in shaded places. All these tree and shrub species are native; there were no phanero-phytes of foreign origin. In total, 1019 trees and shrubs

were inspected for the presence of ants on them.

2. Category X11: Large parks (study sites 9–17). Urban parks, usually >5 ha, with more or less cultivated vegetation (mown lawns, flower beds, shaped shrubberies); they may include small semi-natural or artificial woods, grasslands and water bodies. In the studied parks, we inspected especially tree and shrub clusters (up to 2 ha) and rows along avenues. A total of 1480 plants, both of native and alien origin, mainly constituting the canopy layer were examined. Native

phanerophyte species included (in brackets, the numbers of trees/shrubs examined): *Acer platanoides* (292), *Betula pendula* (173), *Tilia cordata* (167), *Quercus robur* (149), *Pinus sylvestris* (90), *Populus nigra* (58), *P. alba* (45), *Sambucus nigra* (30) and *Fraxinus excelsior* (25). The following species were alien, including four invasive ones: *Robinia pseudoacacia* (112), *Quercus rubra* (77), *Amorpha fruticosa* (60) and *Padus serotina* (30); the rest of the introduced species were *Aesculus hippocastanum* (107), *Juglans mandshurica* (40) and *Acer saccharinum* (25).

3. Category G5.1: Lines of trees (study sites 1, 5, 6, 8 and 18). More or less continuous rows of trees forming strips within a matrix of grassy or cultivated land or along communication arteries, typically planted for shelter or shading. During the research, a total of 1413 trees were examined. We considered trees, which were planted along the roads within the city borders and those creating shelterbelts in the fields. There were three sites with different types of plant associations in this habitat.

First site: Trees formed two layers – overstory layer - *Salix fragilis* (71) and canopy layer consist- *Acer negundo* species (222 trees were examined in a biotope, 157 individuals were saplings), near small groups of *Pyrus communis* trees (15), *Populus tremula* (24) and *Py. communis*, *Po. tremula* of native origin.

Second site: Alley- *Juglans mandshurica* (60, introduced species), *Salix alba* (34, native species).

Third site: Planted trees in the yards. Area up to 0.5 ha. *Robinia pseudoacacia* (194), *Acer negundo* (156) (invasive species), *Populus alba* (40), *Tilia cordata* (125), *Ulmus laevis* Pall. (31), *Betula pendula* (40), *Fraxinus excelsior* (49), *Populus nigra* (39), *Acer platanoides* (36), *Quercus robur* (76): native species; *Aesculus hippocastanum* (40), *Acer saccharinum* (137) are introduced plant species and *Quercus rubra* (24) is an invasive species.

4. Category G1.A53: East-European linden forests (study site 3). *Tilia*-dominated forests with *Quercus robur*, *Acer platanoides* and *Ulmus montana* of eastern Central Europe and the southern nemoral zone of Russia, east of the range of *Fagus sylvatica* and, for the most part, of the range of *Carpinus betulus*, and west of the Volga river. In total, 90 trees were examined, all of native species: *Quercus*

robur (30), *Tilia cordata* (30) and *Sambucus nigra* (30).

5. Category G4.F: Mixed forestry plantations (study sites 19, 20 and 21). Mixed coniferous and deciduous planted forests at the age of 70–80 years, in which at least one constituent is of foreign origin or, if composed of native species, then planted in clearly unnatural stands. In the studied pine-dominated forest, a total of 1150 trees and shrubs were examined. The native species were *Pinus sylvestris* (194), *Padus avium* (180) and *Betula pendula* (8), and the invasive ones *Padus serotina* (481), *Amorpha fruticosa* (150) and *Robinia pseudoacacia* (137).

6. Category E2.1: Permanent mesotrophic pastures (study sites 20) and grazed meadows (study site 21). Regularly grazed European mesotrophic pastures of the alliance Cynosurion. This is a classification unit of meadows vegetation based by Braun-Blanquet approach, on fertilised and well-drained soils. In total, 240 tree samplings of four species (60 of each) were inspected: *Populus nigra* and *P. alba* as native phanerophytes, and *Robinia pseudoacacia* and *Acer negundo* as invasive ones. In the studied site, they grew as single-species clumps.

7. Category G5.2: Small deciduous anthropogenic woodlands (study sites 19, 20). Plantations and small intensively-managed deciduous woods with an area smaller than 0.5 ha. A plantation of the invasive *Robinia pseudoacacia* was studied, where 217 trees of this species were examined (30-40 years old).

8. Category G1.11: Riverine *Salix* woodland (alliance Salicion albae; sites 4, 7 and 22), Floodplain forests. In total 830 plants were examined. *Populus alba* (a total of 60 trees were examined in a biotope, a native species, overstory layer), *Acer negundo* (a total of 73 trees, an invasive species, canopy layer). Other distribution of layers: *Populus alba*, *Populus nigra* (88): native species, *Salix fragilis* (65), *Acer negundo* (73, invasive species, canopy layer), *Quercus robur* (73, native species, overstory layer), *Ulmus laevis* (36, native species, canopy layer). At another point, light forest, without a clear division into layers: *Populus alba* (saplings, 80), *Populus nigra* (91), *Populus tremula* L. (25, native species), *Salix fragilis* (invasive species). In Ukraine, *S. fragilis* is an invasive species (Protopopova et al., 2009). *Amorpha fruticosa*

(239, invasive species) here forms an understory layer.

9. Category G1.C2: Exotic *Quercus* plantations (site 1). Cultivated (more or less single-species) formations of the introduced *Quercus* species (e.g. *Q. rubra*) of the age group 30-50 years, planted most often for the production of wood. A total of 313 plants were examined: 263 of the invasive *Q. rubra* and 50 of the native *Acer campestre*.

Characteristics of the invasive phanero-phyte species within the study area

Among the introduced tree and shrub species, four species in Ukraine are transformer species: *A. negundo*, *Am. fruticosa*, *R. pseudoacacia*, *S. fragilis*. (Protopopova *et al.*, 2009; Burda *et al.*, 2018). All of them occur within our study area:

Acer negundo - is a kenophyte of North American origin. The range is Holarctic. The transformer species, whose influence on biotopes is manifested in the suppression of undergrowth and seedlings of other trees, and also leads to a significant depletion of the grassy layer and also changes in such ecosystems; it occurs in anthropogenic, semi-natural and natural ecotopes (Protopopova *et al.*, 2009). Due to its biological properties (high seed productivity, methods of propagation, the formation of a powerful seed bank, greater plant viability, etc.), a wide ecological amplitude contributes to the penetration and consolidation of the species in the free ecosystems of most biotopes.

Amorpha fruticosa is a kenophyte of North American origin and has a European-American (according to other data, cosmopolitan) range. It is found in anthropogenic, semi-natural and natural ecotopes. It is a robust transformer species, because it changes the soil conditions through enrichment with nitrogen, and also affects the light regime through strong shading. In addition, it plays an active coenotic role, especially in coastal cenoses, forming communities of the riverbed tree-shrub vegetation, which are considered at the level of individual syntaxa, withstands fluctuations in water levels and flooding. These features, as well as the capacity for hydrochlovia, contribute to the mass dispersal of *A. fruticosa* on floodplains and other periodically flooded areas.

Robinia pseudoacacia – kenophyte, has holoarctic distribution, and this species is of North American origin. The transformer species, whose influence on biotopes is manifested in the enrichment of soil with nitrogen compounds, as a result of which only nitrophilic grass species can live here. Also, the ability of rapid growth, and the emergence of a large number of shoots of root origin plus high seed productivity give them an aggressive life strategy. Due to its biological properties (high seed productivity, the formation of a powerful seed bank, a large vital ability of plants, allelopathic properties, etc.), as well as a wide ecological amplitude contribute to its penetration and fixation in the empty habitats of biotopes. The species forms spontaneous mono-species communities or settles in the undergrowth and on forest edges, changing their structure and affecting the functioning of forest ecosystems.

Salix fragilis is an archeophyte, has Euro-Mediterranean-Persian distribution and Asia Minor origin; transforming species, whose influence on biotopes is carried out through the rapid growth and capture of new territories. This is facilitated by its frost resistance and active vegetative reproduction. Occurs in anthropogenic, semi-natural and natural ecotopes (Protopopova *et al.*, 2009). Due to its biological properties (large vital ability of plants, phenotypic plasticity, etc.), as well as the ecological plasticity of the species, it easily penetrates and is fixed in free ecosystems of biotopes. The species completely changes the structure of the recipient ecosystems, which is prone to hybridization with the local species *S. alba*, hampering the natural development of native species populations (Burda *et al.*, 2018).

Fieldwork

In total, 6662 plants (trees and shrubs) of 27 species were inspected; 18 species were recognised as native, 5 species as of foreign origin but not-invasive, and 4 species were considered as invasive (or introduced plants). The inspection was aimed at determining the general presence of aphids and ants of the given species on the plant, as well as the presence of possible ant foraging trails and ant nests in the trunks, lower branches or at the base of the tree. The latter applied especially to dendrobiotic species, such as *Dolichoderus quadripunctatus* (L.), *Lasius brunneus* (Latr.),

L. emarginatus (Ol.) and *L. fuliginosus* (Latr.). As an index of the approximate ant abundance on a plant, the number of workers recorded during a two-minute observation was assumed. On large trees, ants were counted on the whole perimeter of the trunk up to a height of 2 m. On trees and shrubs lower than 2 m, ants on the entire plant were counted. The presence of ants on individual plants was checked once in the study period except that on locusts (*Robinia pseudoacacia*). For the latter, as an example of a typically invasive tree species, such observations were made twice in the season: during flowering in June, and during seeding in July. Ants, if possible, were identified to the species on the spot. When it was impossible, as in cases of the genera *Myrmica* and *Temnothorax*, individual ants were collected and identified in the laboratory based on the key given by Radchenko A. G. (2016). For each of the studied habitats, the proportion of each ant species was calculated. In total, 37870 ant individuals of 21 species were recorded.

At the same time, the presence of aphids on the plants was recorded. On shrubs and small trees their presence was found directly, while on large trees indirectly, based on ants coming down the trunk with their gasters distended with honeydew. Proportions of plants with and without aphids were determined for each plant species separately for each habitat studied. The aphids present on each plant species were sampled to 70% ethanol for subsequent identification. 61 aphid species were recorded. Species of aphids identification was carried out by V.V. Zhuravlev using the key to species of Blackman and Eastop (1994).

For plants studied, we calculated the trunk circumference at a height of 1.6 m (if applicable), life form (sapling, shrub or tree), minimum/maximum of the level of illumination in the habitat, as well as the average level of illumination under the canopy, and the projective cover of the crown (given in % from clear space). Using a Solar Power Meter CEM DT-1307 light meter, the absolute value of the illumination intensity (in lux) was measured, and then the relative value (in %) was calculated as the ratio of the intensity of illumination over plants in the study area to that in the open area.

Statistical analysis

For statistical data processing, the Origin program was used (v.8.0). The distribution of ants on plants of all species, excluding those on which ants were absent or those which were rarely visited, did not differ from the normal one (the Shapiro–Wilk Normality test; Shapiro and Wilk, 1965). This determined the choice of parametric data analysis methods (Pearson correlation between signs, t-test for the significance of differences at $p < 0.05$, cluster analysis). The cluster analysis was carried out according to two defining indicators: the species of ants on different species of plants and the plant species visited by ants. The construction of dendrograms of hierarchical cluster analysis was performed using the Ward method based on Euclidean distances. To determine the similarity of the distribution patterns of species of ants and plants in habitats, canonical correspondence analysis (Ter Braak, 1986) was used, which is one of the variants of multidimensional analysis. The calculation procedure was carried out in the ade4 package (Dray and Dufour, 2007) for the R computing environment (R Core Team, 2018).

To analyze the relationship between the abundance and frequency of species with factors, double co-inertia methods were used (the co-inertia analysis performs a double inertia analysis of two tables). For the analysis of these environmental factors, the standardized PCA method was used; for the abundance of species, centered PCA was used.

When studying the relationship of the frequency of species with factors, correspondence analysis (CoA) was applied to the data on species of ants, normalized PCA was applied to the data on the factors after deleting information related to differences in the abundance of species in locations. To exclude detection of a hidden relationship between the type of habitat and variation of the abundance of species in ant assemblages, constrained Double Principal Coordinates Analysis (cDPCoA) was used (Dray *et al.*, 2015).

Results

Species composition of ants: In total, 21 species of ants belonging to 3 subfamilies were found on native and invasive plants (See supplementary Table 2). They were: *Formica cinerea* Mayr, 1853; *F. rufibarbis* Fabricius, 1793; *F. cunicularia* Latreille, 1798; *F.*

polychaeta Foerster, 1850; *F. rufa* Linnaeus, 1761; *F. fusca* Linnaeus, 1758; *Lasius niger* (Linnaeus, 1758); *L. emarginatus* (Olivier, 1792); *L. platythorax* Seifert, 1991; *L. fuliginosus* (Latreille, 1798); *L. brunneus* (Latreille, 1798); *L. umbratus* (Nylander, 1846); *Camponotus ligniperda* (Latreille, 1802); *C. vagus* (Scopoli, 1763); *C. fallax* (Nylander, 1856) (15 species, subfamily Formicinae); *Dolichoderus quadripunctatus* (Linnaeus, 1771) (1 species, subfamily Dolichoderinae); *Myrmica rubra* (Linnaeus, 1758); *M. ruginodis* Nylander, 1846; *Leptothorax muscorum* (Nylander, 1846); *Temnothorax crassispinus* (Karavaiev, 1926); *T. tuberosum* (Fabricius, 1795) (5 species, subfamily Myrmicinae). Of these, 16 species of ants were found on invasive plants (all but *L. umbratus*; *Camponotus ligniperda*, *F. cunicularia*, *F. rufa*; *F. fusca*) and all the 21 species of ants on native ones.

The distribution of ant species in habitats and associations

The most common ant species include *L. niger*, *F. cinerea*, *L. fuliginosus*, *L. emarginatus* (Table 1). These species are massively found in no less than 6-8 habitats. The first two species can comprise from 5.0 % to 48.0 % of all ants in each of the habitats.

Other ant species are either found in one habitat (*F. rufa*, *F. polychaeta*, *F. rufibarbis*, *C. ligniperda*), or make up a small fraction of all ants in several habitats (*D. quadripunctatus*, *L. brunneus*, *Myrmica spp.*, *C. fallax*, *C. vagus*, *L. platythorax*). The total number of ant species in habitats differs by almost four times: the maximum is recorded for habitats G1.A162 and X11 (14 and 13 species), the minimum is in E2.1 (3 species). The numbers of ants for *C. vagus*, *C. ligniperda*, which forages mainly in the evening, when other dominants are less active, are underestimated in our studies, since during the surveys there was a minimum of their foragers at the forage area.

The most common ant species can make up more than a third of all the ants found in a habitat (*L. niger*, *F. cinerea*, habitats X11, G5.1, E2.1) and occupy a dominant position in the multi-species ant assemblages. Other ant species that are obligate dominants in ant associations (*L. fuliginosus*, *F. rufa*, *F. polychaeta*, *F. cinerea*, in: Zakharov classification, 1991) or facultative (*L.*

emarginatus, *C. vagus*, *C. ligniperda*, *L. niger*) dominants significantly influence the structure of ant assemblages in forest and forest park habitats. In addition to dominants, associations include subordinate species: subdominants (*L. brunneus*, *D. quadripunctatus*, *C. fallax*), as well as influents (other species of ants).

Among the species of ants (Table 1), the differences relate to the share of each of them in the association. The largest total number of ants was observed in habitats G1.A162, X11, G5.1 (Table 1), the smallest - in habitats E2.1, G5.2, G1.C2. The average number of ants per plant is maximum in G1.A162, X11, G1.A5 habitats (Table 1), 1.4 times less in G5.1 habitat, 2.6 times less in G5.2, G1.C2, G1.11, 5.9 times - in habitats G4.F and E2.1 ($p < 0.05$).

The maximum number of individuals per plant and the total number of ant species is noted for habitats G1.A162, X11, in which either native species of plants (G1.A162) are present or invasive species make up less than half of the total. In the deciduous forest (G1.A162), species of ants are represented more evenly, without the overwhelming numerical dominance of one of them. The habitat G1.A5 has a similar structure, where we surveyed a small number of plants. In the X11 habitat, two species of ants, *L. niger*, *F. cinerea*, already dominate.

The same ratio of ant species, but with less attendance, is preserved in the planting of red oak in the G1.C2 habitat, which forms mono-species communities or dominates in the first layer. The participation of forest ant species (*L. fuliginosus*, *L. emarginatus*, *L. brunneus*, *D. quadripunctatus*) is preserved in the habitat G5.1, but their proportion is less significant than in *L. niger*, *F. cinerea* (Table 1). In other habitats, low attendance by ants was noted with a large number of invasive plant species or the participation of these species in the community (for example, *P. serotina* in the pine forests, the habitat G4.F, or *Am. fruticosa* in the floodplain forest, the habitat G1.11), including unattractive for ants (*Ac. negundo*, *Am. fruticosa*, *Ae. hippocastanum* and others). Among the ant species in such habitats, *L. niger* prevails as a rule.

In the hierarchical structure of ant species compiled by the distribution of species in habitats, 4 clusters can be distinguished (Fig. 2).

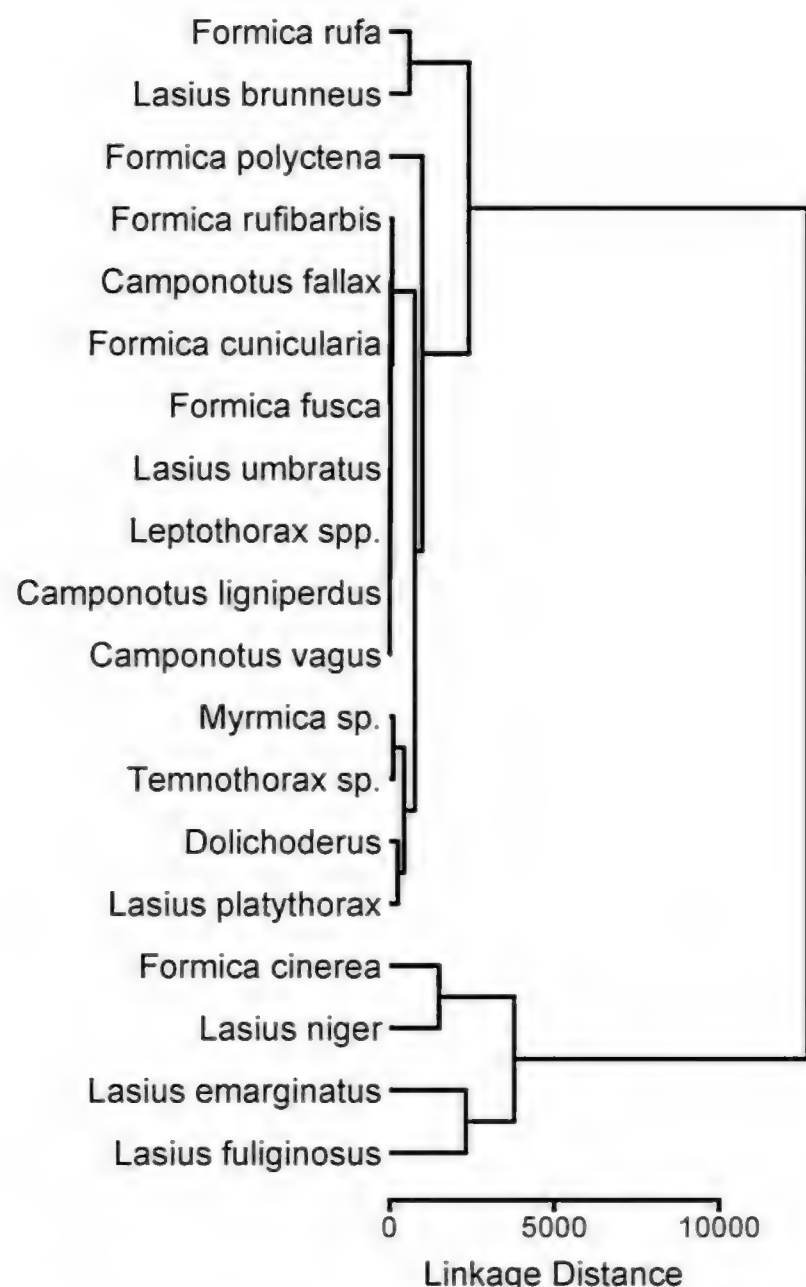


Figure 2: Dendrogram of the species composition of ants in biotopes by association (see also Fig. 5a)

The first cluster includes widespread dominants-dendrobionts in deciduous forests: *L. fuliginosus*, *L. emarginatus*. In addition to forests, they are often found in parks, yards and squares on trees (in G5.1), that is, in habitats, where forest vegetation is still preserved. These species form the core of forest ant assemblages. In the absence of these dominants, two species of ants are widely represented - *L. niger*, *F. cinerea* (in X11, G5.1), included in the second cluster. These are the most common species of ants in habitats of varying degrees of disturbance as a result of human activity.

Separate cluster form *F. rufa* and *L. brunneus*, often found together. Despite the fact that *F. rufa* is an obligate high territorial dominant, *L. brunneus* is able to coexist with it, foraging on drying out oaks in closed tunnels, inaccessible to red wood ants.

The fourth cluster includes ant species represented in native plant communities — forests (pine and broadleaved, habitats G1.A162, G4.F, G1.A5), and also in meadows (*F. rufibarbis* in E2.1). These associations also

include red wood ants (*F. polyctena*), but they are much less common than other dominants (like the second species, *F. rufa*) and only in two habitats. The ratio between the most widespread species in all types of forests — broadleaf, coniferous, floodplain, as well as in forest parks and artificial habitats with areas of forest vegetation (Table 1) is changing.

The ant species which visit the maximum number of plant species in all habitats: *L. niger* - 22 species of 27, *F. cinerea*, *L. emarginatus* - 20 species, *L. fuliginosus*, *L. brunneus* - 15 species each, 18 species - *D. quadripunctatus*; *Myrmica* spp., *C. fallax* - 14 species each. 12 species - *Temnothorax* spp., 11 - *L. platythorax*. Other ant species visited 1-7 plant species.

By species, plant species in habitats belong to one cluster (Fig. 3). Outside the cluster are native species (*Q. robur* and *Ac. platanoides*). Pedunculate oak (*Q. robur*), the most attractive tree for ants. It was visited by 17 species of ants.

The rest of the plants are less attractive to ants. So, *Ac. platanoides* is visited by 13 species, *R. pseudoacacia* and *Pi. sylvestris* - 12 species each, *Q. rubra* - 10 species, *C. betulus* - 9 species of ants. 8 species were marked on *F. excelsior*, *Po. alba*, *T. cordata*, *B. pendula*, *Po. nigra*, *Ac. saccharinum*. On the remaining plants 3-7 species of ants were found. Of the invasive species the lowest number of species of ants was observed on *Ac. negundo* (5), *Am. fruticosa* (4). Thus, invasive species of phanerophytes can have different effects on the species richness of ants, entering both the groups with a high number of species and with a minimum. At the same time, the mass attendance of trees by ants better reflects the attractiveness of plants for ants.

General analysis of the influence of factors on the distribution of ants in assemblages

The relationship of abundance (species abundance) and relative frequency of species is expressed with environmental factors (illumination, canopy cover, the presence of aphids, the species of plants, their shape or age status (shrub, tree, saplings), the stem perimeter, as well as their origin and invasiveness (species origin 'nativeness'), as well as their behaviour and impacts ('invasiveness')).

Table 1. Distribution and mass character of ant species in habitats (in %)

Habitat	G1.A162	X11	G5.1	G1.A5	G4.F	E2.1	G5.2	G1.C2	G1.11
Ant species									
<i>Lasius niger</i>	0	43.0	45.0	0	0	36.0	5.0	20.0	40.0
<i>Formica cinerea</i>	2.0	32.0	16.0	0	48.0	36.0	0	0	5.0
<i>Myrmica</i> spp.	4.0	< 0.1	0	3.0	< 0.1	0	0	13.0	1.0
<i>Formica rufa</i>	16.0	0	0	0	0	0	0	0	0
<i>Lasius fuliginosus</i>	29.0	5.0	21.0	27.0	15.0	0	27.0	36.0	39.0
<i>Lasius brunneus</i>	4.0	4.0	5.0	11.0	< 0.1	0	17.0	4.0	6.0
<i>Lasius platythorax</i>	3.0	0	0	< 0.1	7.0	0	0	0	0
<i>Temnothorax</i> spp.	5.0	< 0.1	< 0.1	6.0	< 0.1	0	< 0.1	4.0	0
<i>Formica fusca</i>	< 0.1	0	0	0	< 0.1	0	0	0	0
<i>Camponotus fallax</i>	< 0.1	< 0.1	< 0.1	0	0	0	3.0	< 0.1	< 0.1
<i>Camponotus vagus</i>	0	< 0.1	0	0	< 0.1	0	0	0	0
<i>Camponotus ligniperda</i>	< 0.1	< 0.1	0	0	0	0	0	0	0
<i>Dolichoderus quadripunctatus</i>	2.0	2.0	1.0	8.0	0	0	1.0	4.0	2.0
<i>Leptothorax muscorum</i>	0	< 0.1	0	0	< 0.1	0	0	0	0
<i>Lasius emarginatus</i>	35.0	14.0	12.0	45.0	0	0	47.0	19.0	6.0
<i>Formica rufibarbis</i>	0	< 0.1	< 0.1	0	0	28.0	0	0	< 0.1
<i>Formica cunicularia</i>	< 0.1	0	0	0	0	0	0	0	0
<i>Formica polychaeta</i>	0	0	0	0	28.0	0	0	0	0
<i>Lasius umbratus</i>	0	0	0	0	0	0	0	0	1.0
Total number of ant species in a habitat	14	13	9	8	10	3	7	10	10
Total number of worker ants counted in a habitat N + (I%)	7821 (20.6)	14448 (38.1)	8361 (22.0)	603 (1.5)	2169 (5.8)	257 (0.7)	809 (2.2)	810 (2.2)	2592 (6.9)
Total number of plant specimens recorded in a habitat N + (I%)	929 (14.0)	1480 (22.2)	1413 (21.2)	90 (1.3)	1150 (17.3)	240 (3.6)	217 (3.3)	313 (4.7)	830 (12.4)
Average number of recorded ants / 1 plant / 2 min in a habitat	8.34± 0.90	9.76 ±1.22	5.91± 0.40	6.70 ±1.51	1.88 ±0.34	1.07± 0.19	3.72 ±1.06	2.67 ±0.36	3.13 ±0.47

Note. Vertically - 100% - the total number of all ants recorded in a habitat, horizontally - 100% - the total number of ants and plant individuals in all habitats.

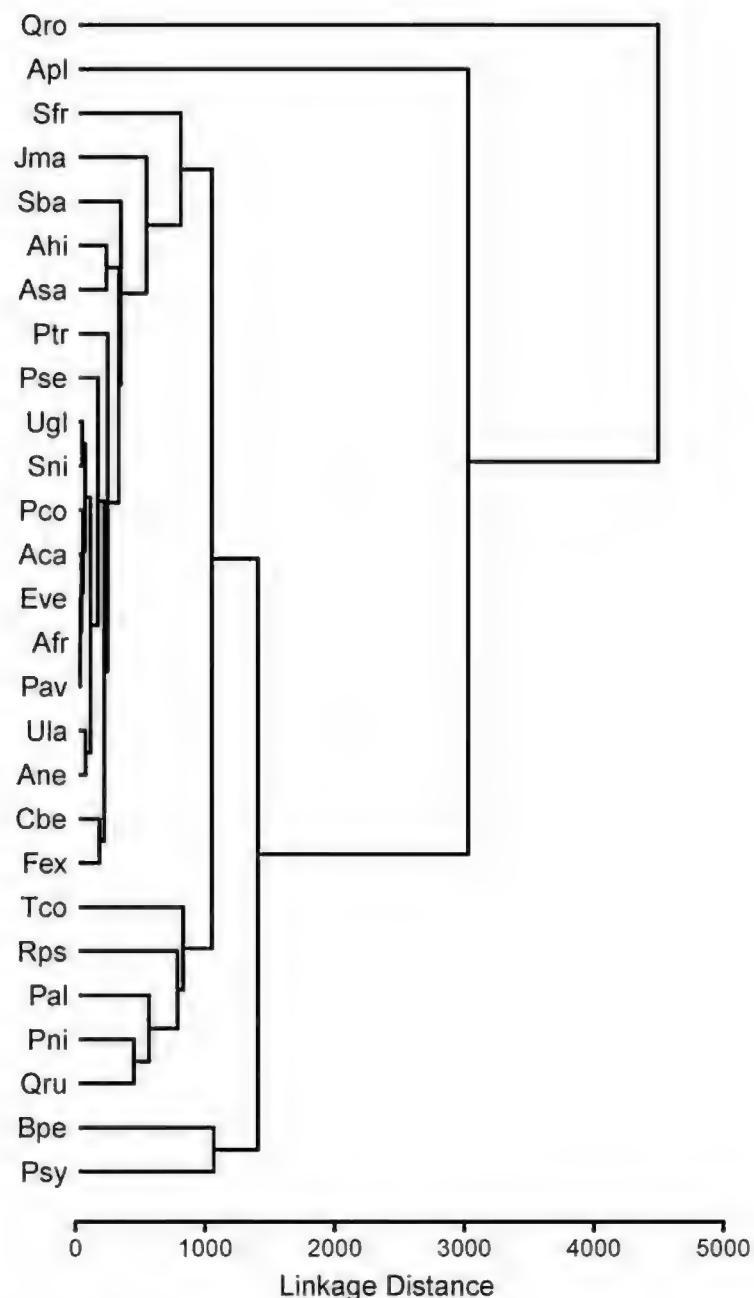


Figure 3: Dendrogram of ant's attendance of plant species in biotopes.

The analysis of co-inertia showed a low correlation between the abundance of species in individual locations and a complex of environmental factors, RV coefficient is less than 0.06, although it is clearly visible for some species of ants and individual factors (Fig. 4 a and b). Some environmental variables have a similar effect on the abundance of ant species (aphid presence and lifeform; stem perimeter, canopy cover and tree species) or the opposite, for example, canopy cover and illumination, aphid presence and plant origin (nativeness). The connection of the abundance of a species with environmental factors is more pronounced than in others in *L. niger*, *L. fuliginosus*, *L. emarginatus*, *F. cinerea*, *F. rufa* (Fig. 4a). The main drivers of an abundance of ant species are: the presence of colonies of aphids, the size of the tree trunk, the luminance (or crowns density) (Fig. 4b). Aphids on trees to be the most important for *L. niger* and *F. cinerea*, which form a separate cluster, *L. fuliginosus* and *L. emarginatus*, *L. brunneus* and *F. rufa* (see the dendrogram on the right in Figure 5a). The size of the trunk

has a similar effect and is combined with the previous factor in the cluster (left dendrogram Fig. 5a). The high abundance of *F. cinerea* is also associated with the woody life form of plants. The association of the abundance of other species with environmental variables is not obvious or disguised.

The influence of a complex of factors on the relative frequency of species is more pronounced than on abundance, RV coefficient - 0.11. The similarity of the effect of environmental variables is preserved, for example, the correlation of cover-origin-tree and circum-ap, but their meaning (loadings) differs from the previous analysis (Fig. 4d-e, Fig. 5b). So, the main factor is the life form / age state (form), which also reflects the layer. The effect of this factor is maximum and correlates with the size of the trunk, the presence of aphids and the type of tree according to the first component. For the second component, the second most loaded factor after the form is canopy cover (or illumination). The relationship of the relative frequency of a species with environmental variables, primarily the life form — the age state — is most pronounced for *Myrmica* sp., *Temnothorax* sp., forming a separate cluster according to the similarity of the response to factors (Fig. 5b). In *F. rufibarbis*, the relative frequency is also higher in the lower layer, but in low light there is a negative correlation with il (relative illuminance). A separate cluster (Fig. 5b) forms *Leptothorax* spp., *C. vagus*, and *F. fusca*, the relative frequency of which is higher in trees of the native flora fraction - a positive correlation with an origin, and for *F. rufa* the size of the tree is crucial (circum). The influence of the origin and invasiveness of the tree species (origin) on the relative frequency of ant species is not obvious. Habitats are poorly separated by variations in the relative frequency of species, but their ellipses of variation are oriented along form or circum factors, which isolates the E2.1 habitat, in which the presence of plants of low-layer and high illumination create favorable conditions for *F. rufibarbis* (Fig. 4e).

Although the classical analysis of covariance does not allow separating the assemblages of ants in separate habitats (Fig. 4d), removing variations related to plant size by the cDPCoA method, the difference in the assemblages of ants in habitats has become more apparent.

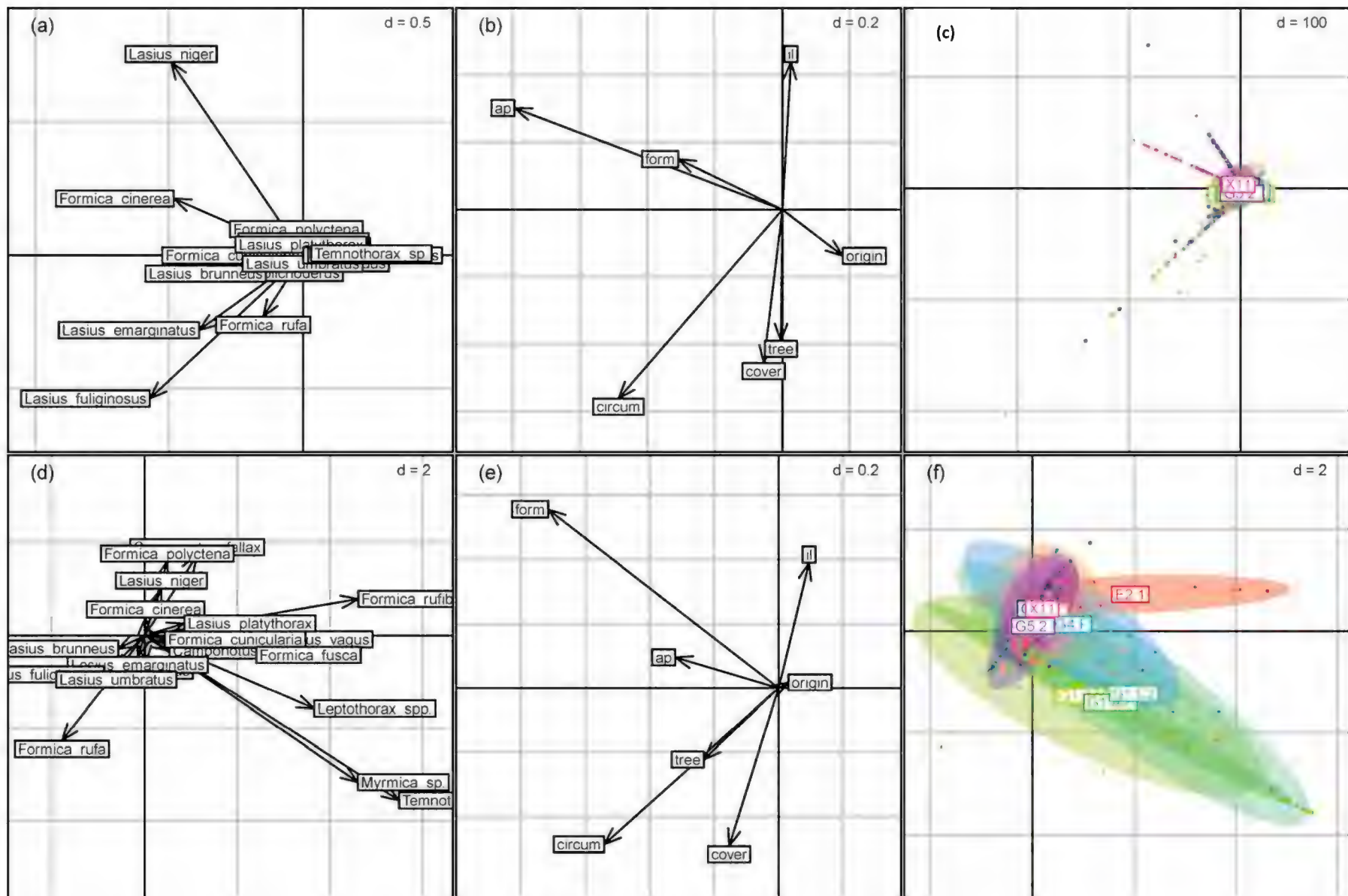


Figure 4: The co-inertia analysis of two data sets (ant species and environmental variables). **Panels a-d:** PCA-PCA COIA based on absolute ant's species composition. **Panel a:** factor map of the ant species abundance. **Panel b:** the factor map of environmental variables. **Panel c:** species-constrained locality scores groped by habitats. The ellipsoids represent species association variability within habitats. **Panels d-f:** Same as in panels a-d, but for PCA-CA COIA based on ant species' relative frequency. Code for environmental variables: ap – aphids' colonies presence on trees; circum – trees stem perimeter, cover – canopy cover; form – life form and life history stage of woody plants, il – relative illuminance; origin – woody plant origin ('nativeness') and 'invasiveness', tree – woody plant species

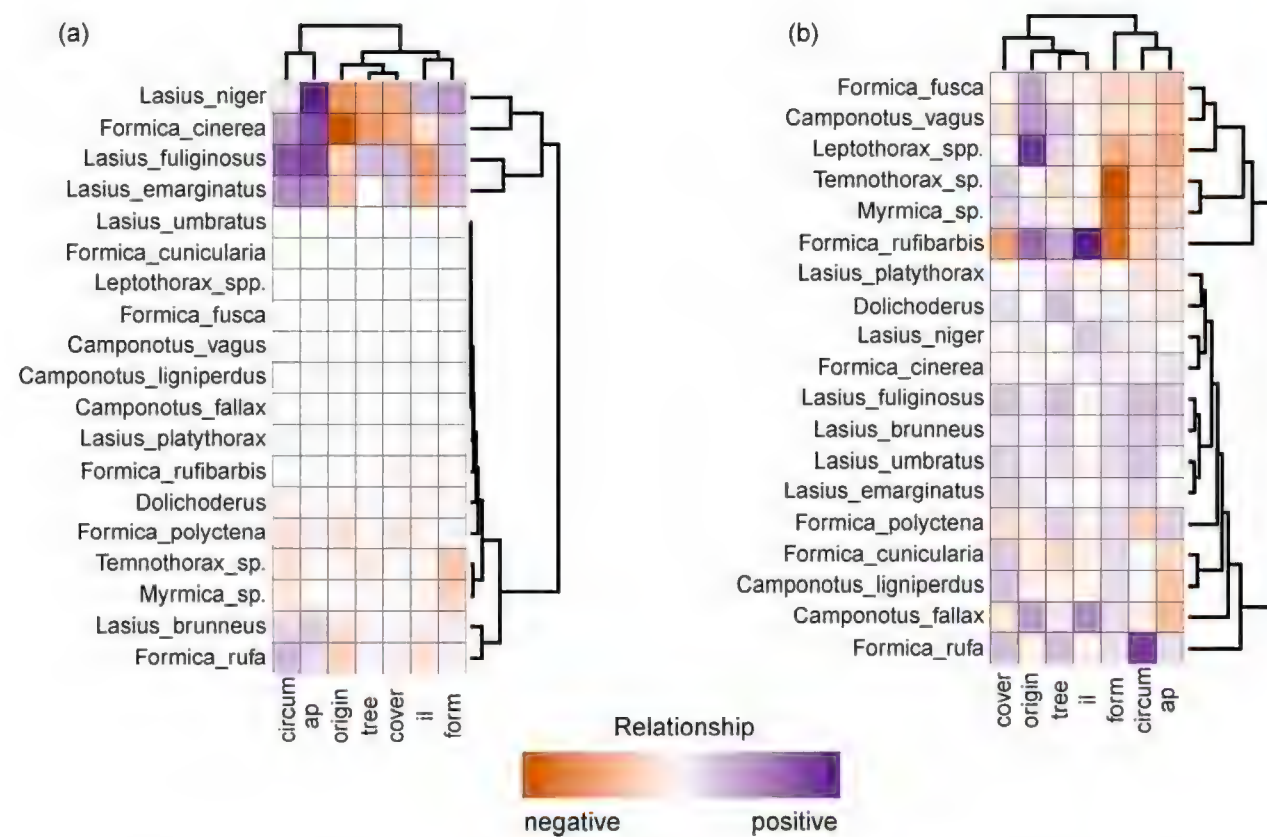


Figure 5: The crossed table coefficients resulted from COIA. **Panel a:** relationships between ant species abundance and environmental variables. **Panel b:** same as in panel a, but for species relative frequency. The dendrograms are the results of crossed table coefficients running through the Average hierarchical clustering algorithm. (see Fig. 4 for environmental variables cod)

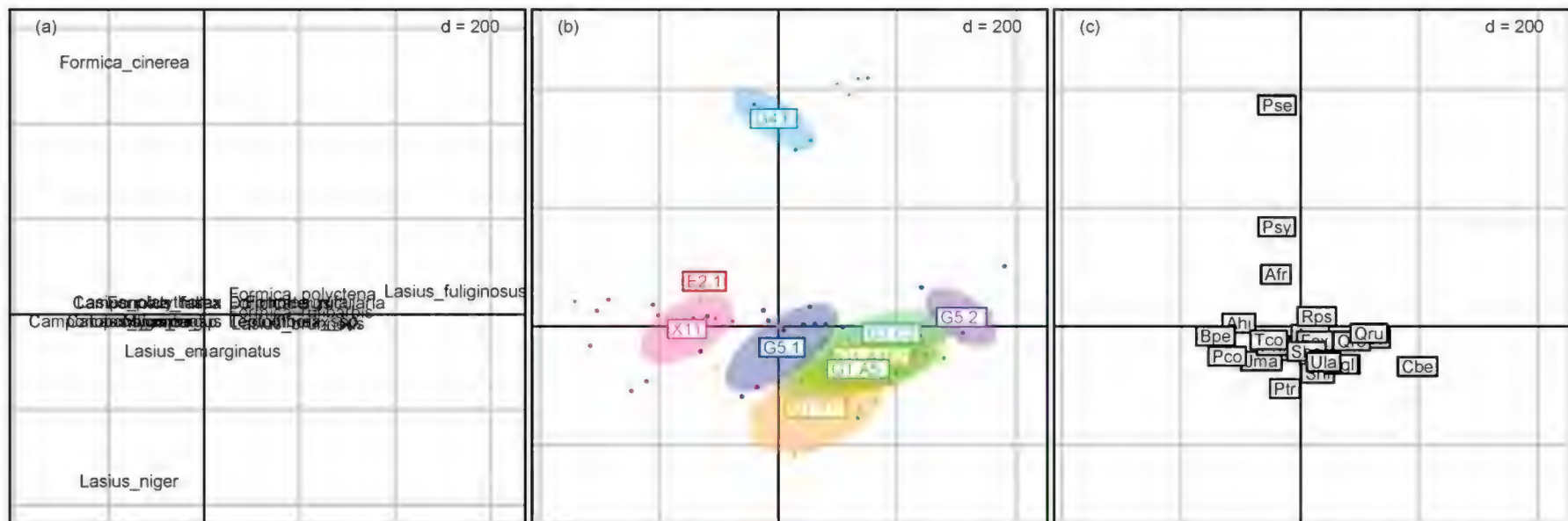


Figure 6: Panel a: The effect of each ant species in association variability. **Panel b:** Decomposition of the ants' association according to habitat type resulting from between-class analysis (cDPCoA), in which the effect of plant size has been removed. **Panel c:** The effect of plant species on ant community variation (see Fig. 4 for environmental variables cod)

The percentage variation in species abundance unrelated to plant size was 12% ($p < 0.001$). The differences in habitats in ant assemblages are associated with the dominance of *F. cinerea*, *L. niger*, *L. fuliginosus*, and *L. emarginatus* in habitats, where there are high incidence of invasive species in the studied areas (Fig. 6 a-c). Thus, workers of *F. cinerea* were found in large numbers in G4.F (67% of invasive woody plants), including the invasive species *Padus serotina*. In E2.1. (50% of invasive species) *F. cinerea* with co-dominant *L. niger* are found on invasive *Robinia pseudoacacia*. *L. niger* has a high abundance in X11 (~ 20% of invasive trees), where besides native species it is abundant on *Quercus rubra* and *Robinia pseudoacacia*. In G5.1, invasive plants (~ 50%) showed a high abundance of not only *L. niger* and *F. cinerea*, but also other species of ants. *L. fuliginosus*, and *L. emarginatus* influence the variation of associations due to the high abundance of introduction of invasive plants in G1.C2 (~ 80% of invasive trees) and G5.2 (~ 100% of invasive woody plants).

The attractiveness of different species of plants for ants in different habitats

The plant species most widely visited by ants is the pedunculate oak (Supplementary Table 1). From 7 to 23 ants / 2 min were found on oak trunks. Oak is followed by maple (*Ac. platanoides*) and white poplar (*Po. alba*), on which from 6 to 16 ants / 2 min in different habitats. The well-visited plants by ants also include linden (*T. cordata*), birch (*B. pendula*), pine (*Pi. sylvestris*), red oak (*Q. rubra*),

Manchurian walnut (*J. mandshurica*) and, to a lesser extent, *Robinia (Ro. pseudoacacia)*. The following species are practically not visited by ants: *Ac. negundo* (0.006 to 0.5 / 2 min), *Pa. serotina* (from 0 to 0.45), *Am. fruticosa* (from 0 to 0.4), hornbeam (*C. betulus*, 1.8), Euonymus (*E. verrucosus*, 0.2). The remaining species of plants are visited by ants to a greater extent, but not as actively as plants with maximum attendance.

According to the average ants attendance of phanerophyte for all habitats, we can distinguish several groups in descending order. The first group includes oak (*Q. robur*), maple (*Ac. platanoides*), as well as weeping willow (*S. alba*), all native species widely visited by ants (12-16 ants / 2 min). The second group includes plants that are 1.5-2.0 times ($p < 0.05$) less visited by ants - *Po. alba*, *T. cordata*, *B. pendula*, *Pi. sylvestris*, *Q. rubra*, *S. fragilis*, *J. mandshurica*, *Po. tremula*, *Po. nigra* (6-8 ants / 2 min). Of these, 1 species is invasive (*S. fragilis*), 2 are introducents (*Q. rubra*, *J. mandshurica*). The remaining 6 species are native. The third group consists of species with attendance of 6-8 times less than that of plants of group 1 (1-3 ant / 2 min, with $p < 0.05$). These include the following species of phanerophytes: *Ae. hippocastanum*, *Ac. saccharinum*, *Py. communis*, *R. pseudoacacia*, *S. nigra*, *U. laevis*, *F. excelsior*, *C. betulus*, undergrowth of *Ac. platanoides*. Of these, 2 species (*Ae. hippocastanum*, *Ac. saccharinum*) are introduced species, 1 is invasive (*R. pseudoacacia*), and the remaining 6 are native. Finally, the last group is formed by plant species that are practically not visited by ants

(attendance on average 0.3 ant / 2 min, 40-50 times less than that of plants of group 1, with $p < 0.05$). These include the following species: *Ac. campestre*, *Ac. negundo*, *Pa. avium*, *Pa. serotina*, *Am. fruticosa*, *U. glabra*, *E. verrucosus*. Almost half of them are invasive plant species and introducents (*Ac. negundo*, *Pa. serotina*, *Am. fruticosa*). All these species belong to shrubs (*Pa. avium*, *Pa. serotina*, *Am. fruticosa*, *E. verrucosus*) or young trees (*U. glabra*, *Ac. campestre*, *Ac. negundo*). The exception is *Ac. negundo*, unattractive to ants in the form of undergrowth, and in the form of trees. The same features are preserved in plants and in each of the habitats. So, *Ac. negundo* in habitat G5.1 is 27 times less than *S. fragilis* in attendance, as many as in G1.11 habitat in white poplar trees (*Po. alba*) and 83 times in oak (*Q. robur*) right there ($p < 0.05$). For *Am. fruticosa* in the G4.F habitat is 190 times lower in attendance than in pine (*Pi. sylvestris*) and 9 times less than in *Pa. serotina*. The same applies to other plants. In some plants, depending on the conditions of the habitat, attendance may vary. For *R. pseudoacacia* in the X11 habitat, attendance is 3 times less than that of *Po. alba*, and in the habitat G5.1 - almost the same. Some species differ in attendance at different phases of the life cycle. At the undergrowth stage of *Ac. negundo* attendance is 100 times lower than that of mature trees in the habitat G5.1, and in *Ac. platanoides* in the habitat G1.A162 is only 1.8 times less ($p < 0.05$). For *Po. alba* in habitat G1.11 similar data were obtained - 3 times lower attendance of seedlings ($p < 0.05$). For *Q. rubra* in the habitat G1.C2, saplings and undergrowth are 4 times less intensively visited by ants ($p < 0.05$).

Invasive and introduced species are included in all groups, except for those most visited by ants. The attendance rates (maximum or minimum) for different species are preserved in all habitats where these plants are present. In the transition from plants with a maximum to those with a minimum attendance of ants, the number of invasive and introduced species increases. The total attendance of ants prevails on native plant species.

A smaller total number of ants were recorded on introduced species of plants, and a minimum total number of ants were recorded on plants of invasive species. Thus, due to invasive species of plants that are unattractive to ants, abundantly represented in a number of

habitats (*Am. fruticosa*, *Ac. negundo*), their overall impact on the ants' mass visits is negative. For introduced species, the effect is generally neutral.

Trophobiosis of ants with aphids

Ants nest and have food trails on phanerophytes. One of the reasons for the attractiveness of plants for ants is the presence of aphid colonies producing sugary excreta (Fig. 7). Excreta of aphids are the main source of carbohydrate for the ant colony.

On *Am. fruticosa* plants we observed colonies of aphids visited by ants only in isolated cases (Fig. 7A). In some cases (for example, on the red oak trees), there are colonies of aphids numbering hundreds of individuals (Fig. 7B). Colonies of aphids feeding on *Robinia* may not be visited directly by ants. In this case, food was observed in sugary excreta, which fell on the leaves on the lower branches (Fig. 7D). In other cases, the ants visited the aphids (Fig. 7C). On *P. serotina* plants, ants visiting colonies of aphids, were observed only in spring, in April (Fig. 7 E). For white poplar, which is an invasive species north of Moscow, and in Ukraine - a native one, an active visit by ants to colonies of aphids on leaves and young shoots was also observed (Fig. 7E).

Plants whose life forms are perennial (trees, shrubs) have been a resource for ants for many years. Therefore, control over them is a priority for dominant ants with large colonies. The food trails of most dominant species always end in trees, where the aphid colonies are located. According to our data, the average attendance by ants of phanerophytic plants with aphid colonies in all habitats is 10 times higher compared to plants without aphids (3.3 ± 0.05 / 2 min for plants without aphid colonies and 31.7 ± 1.12 / 2 min for plants with aphid colonies, $p < 0.01$). However, different plant species have different ants attendance rates due to different susceptibility by aphids (Table 2).

The most common colonies of aphids are found on pedunculate oak, white poplar, linden, birch, red oak, black poplar, pine, and brittle and weeping willows, sugar maple and platanol maple (from 17 to 40% of the plants examined). Of these, 2 species are introduced species (*Q. rubra*, *Ac. saccharinum*) and 1 - invasive (*S. fragilis*). In this case, pedunculate oak prevails over the rest species of the plants

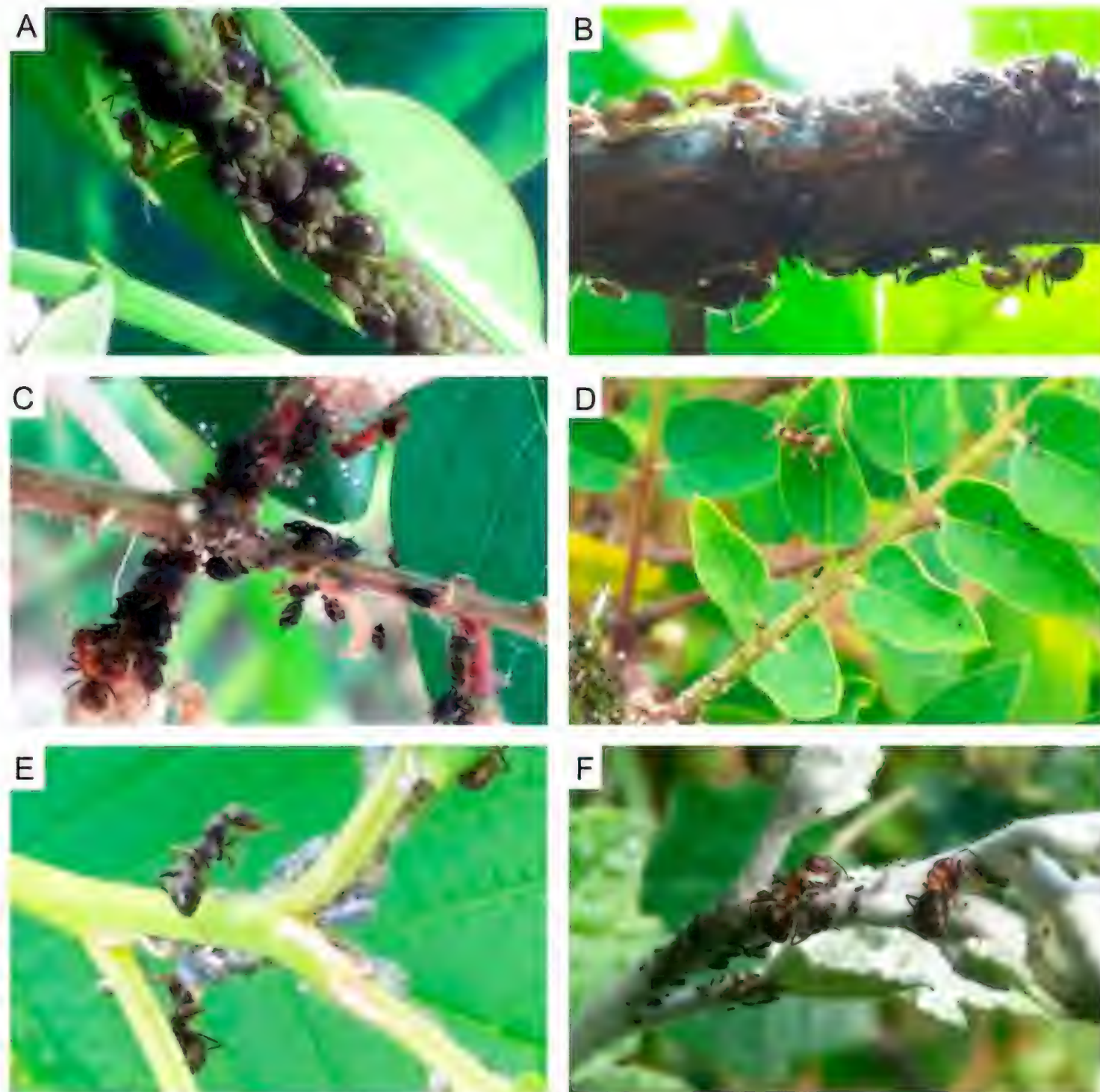


Figure 7: Ants attendance of aphid colonies on native, introduced and invasive species of phanerophytes. **A.** *Amorpha fruticosa*, ants *Formica cinerea* and aphids *Aphis craccivora*; **B.** *Quercus rubra*, ants *F. polystena* and aphids *Lachnus roboris*; **C.** *Robinia pseudoacacia*, ants *Lasius emarginatus* and aphids *Aphis craccivora*; **D.** *R. pseudoacacia*, ants *F. cinerea* and aphids *Aphis craccivora*; **E.** *Padus serotina*, ants *Camponotus vagus* and aphids *Rhopalosiphum padi*; **F.** *Populus alba*, *F. rufa* ants and aphids *Chaitophorus populeti*.

- aphids, visited by ants here on almost every second tree. The second group includes species of phanerophytes with 0.5 - 2.0 times less susceptibility by aphids - aspen, robinia, hornbeam, ash, elder, elm (*U. laevis*), manchurian nut (from 3 to 14%). Of these, 1 species is introduced (*J. mandshurica*) and 1 is invasive (*R. pseudoacacia*). Finally, the third group consists of plants that are practically not populated by aphids, at least those species that are not associated with ants by trophobiosis. Part of the species we studied (*Euonymus* and some others), due to the small sample size, fell into the third group, although there are aphids on them (see below). These include *Amorpha*, both species of bird cherry trees, ash-leaved maple, pear, chestnut, spindle tree and elm (*U.*

glabra), as well as *Acer campestre*. 2 of them are invasive (*Am. fruticosa*, *Ac. negundo*), 2 - introducents (*A. hippocastanum*, *Pa. serotina*). Invasive species of phanerophytes, as well as introducents, in terms of susceptibility by aphids (and, as a result, attractiveness for ants) can be included in all three groups of plants, having both positive, neutral and negative effects.

In the wood of still living plants not all species of ants can nest, but only dendrobionts (see. Material and methods). This is associated with less attractiveness of phanerophytes as habitats for ants (Table 2). The first group consists of pedunculate oak, willow brittle and weeping, as well as white poplar. Only one of the species is invasive (*S. fragilis*). The ants

nesting in these plants in the range of 11-22%. In the plants of the second group, ants are nesting 2-5 times less often (from 2 to 8% of all trees of this species, $p < 0.05$). These are: *C. betulus*, *F. excelsior*, *R. pseudoacacia*, *Po. nigra*, *Po. tremula*, *Ac. saccharinum*, *A. hippocastanum*, *U. laevis*, *J. mandshurica*, *Q. rubra*, *Pi. sylvestris*, *B. pendula*, *T. cordata*, *Ac. platanoides*. Of these, 1 species is invasive, 4 are introduced species. Finally, the third group consists of species in which ants do not build nests in the wood, or these cases are rare: *Pa. serotina*, *Am. fruticosa*, *Ac. negundo*, *Acer campestre*, *Pyrus communis*, *Padus avium*, *S. nigra*, *U. glabra*, *E. verrucosus*. It should be noted that most of them belong to the shrubs and dominant ants in them are not inhabited. On the other hand, ants such as *Temnothorax* spp., *Leptothorax* spp. can even nest on shrubs (in thin stalks or trunks) but they were not included in our records. Ants did not inhabit in *Ac. negundo* trees and in rare cases marked on trees *Pa. serotina*.

As for the food trails of ants, their presence is directly connected with colonies of aphids or with a nest in the trunk of a given tree. The relationship between aphid colonies and food trails is more clearly seen (0.92). This is due to the fact that not all species of ants arrange nests in the trunks of trees (0.44). However, not all trees with nests have colonies of aphids (0.41). Thus, the attendance of ants of trees is primarily associated with the presence of aphid colonies, and only the second with nesting.

The attendance by ants on mature trees, undergrowth and seedlings

Different life forms of the same plant species may have unequal attractiveness for aphids, and therefore for visiting ants. For example, *Robinia* undergrowth is inhabited by aphids 2.0 times more often ($p < 0.05$, Table 2) than mature trees. If maple (*Ac. platanoides*) and white poplar saplings are affected by aphids almost as often as mature trees, then brittle willow and red oak have the opposite effect ($p < 0.05$, Table 2). In general, meristemophilous species of aphids live on the undergrowth, phylobionts can settle equally often on the undergrowth and on adult plants, while the inhabitants of the bark of branches and trunks will be on adult plants.

Undergrowth and trees of *Ac. negundo* are not attractive to ants and aphids. Nevertheless in isolated cases, trees are inhabited by dendrobiontic ants and are visited by individual foragers (Supplementary Table 1). Species of phanerophytes belonging to shrubs, as a rule, are less attractive for ants (*Am. fruticosa*, etc.). For different species of phanerophytes (including invasive ones), mutually opposite tendencies can be observed in visiting undergrowth and mature trees. Some species are unattractive to ants, both in the form of undergrowth and trees.

47 species of aphids (Aphididae) were found on 18 native species of plants-phanerophytes (Supplementary Table 2). For 9 invasive plant species, 14 aphid species were found. Only one aphid species (*Aphis craccivora* Koch) found on invasive plant species is invasive.

The effect of illumination on the attendance of ants on invasive plant species

Among habitats, the maximum average illumination is fixed for G5.2 (Supplementary Table 3), followed by habitats with illumination 1.3 times less (E2.1) and 3.8 times (X11, G5.1, G1.A5, G4.F, G1.11, G1.C2). The minimum illumination in the habitat of G1.A16 is 12 times less. Depending on the species composition of plants, the average light intensity in a habitat will vary. Different species of plants will make a different contribution. For example, *Ac. negundo* enhances shading, as does *Ac. platanoides* (Supplementary Table 3). Under oak trees, which make up 1st layer, the illumination on average in habitats is 1.4–1.5 times higher than that under *Ac. platanoides*. Thus, in the habitat G1.A16, in the second layer, composed of hornbeam and maple trees, the illumination is already worse. In the 3rd layer, composed of bushes, the illumination varies - from 1.4 times smaller under the *Euonymus* (than under the *A. platanoides*, Supplementary Table 3) to 7 times smaller under the *S. nigra* (than under the *A. platanoides*, Supplementary Table 3).

R. pseudoacacia has no significant effect on shading. *Amorpha fruticosa* grows in more illuminated places, but, it is practically not visited by ants. *Padus serotina* at the undergrowth also does not have a significant effect on shading, but when it becomes a tree, it can strengthen it. Overlaying layers on each

other will enhance shading, especially if they include species that contribute to it.

The average number of ants per plant / 2 min in areas with high illumination (from 5% of illumination in open areas) and in areas with low does not differ significantly (up to 5%): In the first case, the average number of ants for 2 min was 11.64 ± 0.70 , in the second 13.68 ± 0.55 . We found no significant correlations between the total number of ants and the level of shading in all habitats.

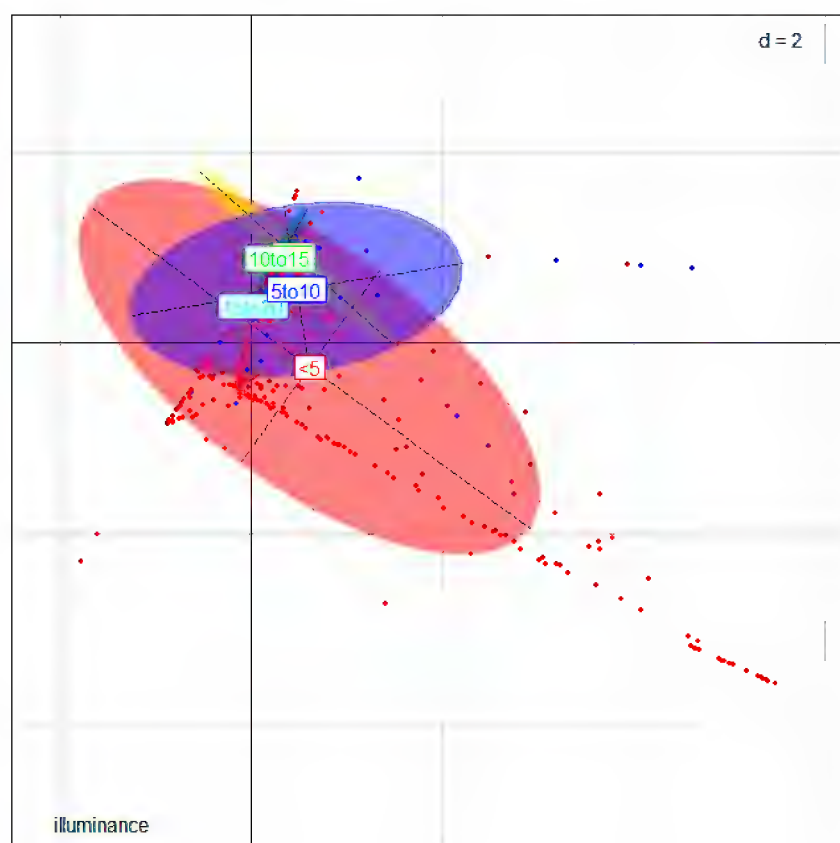


Figure 8: The total number of ants, depending on the level of illumination (up to 5, 5-10, 10 or more% of the coefficient in open areas).

Different species of ants can make the main contribution to the attendance of plants due to their stationary preferences. For example, *F. cinerea* prevails in habitats with a high level of illumination, while *L. fuliginosus*, *L. brunneus*, on the contrary, prefer shaded areas.

With a more detailed comparison of the total number of ants in areas with different illumination, it was found that most of all ants live in habitats with a low level of illumination (Fig. 8).

Approximately 1.5 times less ants were recorded in areas with illumination from 5 to 10%, and at least in well-illuminated areas (from 10%). Thus, the total number of ants in all the studied habitats is inversely proportional to the illumination level.

Ant's attendance on *Robinia pseudoacacia* during the flowering and fruiting phase

Robinia pseudoacacia is one of the two invasive plants we studied, which is a honey plant. The second one is *Pa. serotina*, but for it species we did not conduct studies. We found no difference in attendance by ants between flowering Robinia trees and the same trees during the fruiting (an average of 3.58 ± 0.71 ants per 2 min in flowering and 4.85 ± 1.65 in fruiting ones). At the same time, the number of species of ants on flowering plants is 2.0 times greater ($p < 0.05$): 0.6 ± 0.08 against 0.31 ± 0.06 .

Table 2. The occurrence of colonies of aphids, the number of nests and food trails of ants on plants-phanerophytes

Species of plants	The occurrence of aphids colonies, %*	The number of ants nests, %*	The number of forage trails, %*
<i>Quercus robur</i>	40.36	22.90	40.36
<i>Acer platanoides</i>	29.06 + 10.47 (\$)	6.69	29.06 + 3.80 (\$)
<i>Salix alba</i>	20.58	17.60	20.58
<i>Populus alba</i>	32.41 + 29.28 (\$)	11.72	33.10 + 6.42 (\$)
<i>Tilia cordata</i>	31.98	8.07	31.98
<i>Betula pendula</i>	34.38	2.26	34.38
<i>Pinus sylvestris</i>	20.07	2.81	20.07
<i>Quercus rubra</i>	18.03 + 0 (\$)	5.34	17.69 + 0 (\$)
<i>Salix fragilis</i>	24.26 + 0 (\$)	11.76	24.26 + 0 (\$)
<i>Juglans mandshurica</i>	14.0	6.00	14.0
<i>Euonymus verrucosus</i>	0	0	0
<i>Ulmus glabra</i>	0	0	0
<i>Ulmus laevis</i>	4.47	7.46	7.46
<i>Salix nigra</i>	11.11	0	0
<i>Aesculus hippocastanum</i>	0	2.72	10.88
<i>Acer saccharinum</i>	17.92	5.66	17.92

<i>Padus avium</i>	0	0	0
<i>Pyrus communis</i>	0	0	0
<i>Populus tremula</i>	14.28	4.08	14.28
<i>Acer campestre</i>	0	0	0
<i>Populus nigra</i>	22.7 + 0 (\$)	1.86	22.2 + 0 (\$)
<i>Robinia pseudoacacia</i>	11.06 + 26.6 (\$)	4.39	11.06 + 3.33 (\$)
<i>Fraxinus excelsior</i>	0	7.22	7.22
<i>Carpinus betulus</i>	3.12	6.66	3.03
<i>Acer negundo</i>	0 + 0 (\$)	0.33	0 + 0 (\$)
<i>Padus serotina</i>	0.40	0	0.39
<i>Amorpha fruticosa</i>	0.95	0	0

Note. * - 100% of all trees of this species are taken in all habitats. (\$- saplings)

We did not observe direct visits by ants on flowers. In addition to the dominants of *L. emarginatus*, *L. niger*, the subdominants *L. brunneus*, *C. fallax* were also noted during flowering. Perhaps it is these species of ants that are attracted not only to the excreta of aphids, but also to the nectar of flowers. In addition, it is possible for ants to collect nectar from fallen flowers on the earth's surface, but we did not conduct any special studies on this subject.

Discussion

The attractiveness of invasive phanerophyte for ants

North American species in the flora of Kyiv have the largest proportion (share) among those introduced in the 20th century (Mosyakin and Yavorska, 2002). According to literary data, among invasive plant species, both a positive (or neutral) effect on the species richness of ants and a negative one are manifested. *Robinia* has a positive effect on the cover of nitrophilic and ruderal plant species (Dzwonko and Loster, 1997). Among the 18 studied arthropod taxa in Berlin, Germany, *Robinia* has a negative effect on the abundance of five (Chilopoda, Formicidae, Diptera, Heteroptera, Hymenoptera, according to (Buchholz *et al.*, 2015)). For example, in forest areas dominated by *Robinia*, ant species are 2.5 times less than in areas with birch (6 vs. 14 species, (Weiss *et al.*, 2005)). This is also shown by our data, in the mapping of ants' attendance rates of trees and the undergrowth of *Robinia*, nesting and the occurrence of aphid colonies.

In the EU countries, Poland and Germany, red oak (as well as *P. serotina*, according to (Tokarska-Guzik, 2005)) is one of the most economically significant invasive phanerophytes. Red oak contributes to the

reduction of biodiversity in forest communities, both in the form of seedlings and mature trees. Mature trees have a negative effect on the cover of seedlings of other species, as well as on the shrub layer. Seedlings have a negative effect on seedlings of other tree species (Chmura, 2013). Coating of another invasive species - *P. serotina* negatively correlates with the number of grassy plant species (Godefroid *et al.*, 2005). For red oak, according to our data, in the conditions of Kyiv and the region, ants attendance rates can be attributed to the average among all plants. This plant does not have a clear negative effect on the ant assemblages, which may be a consequence of the development of colonies of myrmecophilous aphids on it.

Nesting: In addition to trunks or branches of trees, ants can be populated on their fruits. The acorns of red oak are intensively populated by ants *Leptothorax ambiguus* Emery in North America (Alloway and Hodgson, 1990). On the territory of the secondary range of *Q. rubra*, in Europe, another species of ants, *Temnothorax crassispinus*, populates acorns of red oak in large quantities, and significantly more than natural oak species (Myczko *et al.*, 2018). For *Ac. negundo* attendance and nesting of ants were not recorded, not only according to our data, but also on the previously obtained data for the parks of Warsaw, Poland (Czechowski *et al.*, 1990). At the same time, other species of invasive phanerophytes were visited and colonized by ants - chestnut (ants: *L. brunneus*, *L. niger*), *Robinia* (*L. brunneus*, *M. laevinodis*). Ants are fixed on red oak trees. As in our case, the most populated and visited trees by ants belonged to natural species - maple (*Ac. platanoides*) and pedunculate oak.

Relationship between invasive phanerophytes and aphids

For aphids, plants from the *Salix*, *Quercus*, and *Betula* genera are most attractive, based on data from Hungary (Csóka, 1998; Csóka, and Hirka, 2002). It is also noted that specialized phytophages almost never colonize red oak plants (Csóka and Hirka 2002; Holman, 2009). Later data showed that red oak in Europe (the Czech Republic and other countries), in addition to natural ones, is colonized by the North American species of aphids *Myzocallis walshii*, which feeds only on this plant (Havelka and Stary, 2007).

Thus, in some cases, red oak can be populated with both invasive and natural aphids and be attractive to ants. This is shown by our observations. For *Pa. serotina* in the Netherlands indicates 13 species of aphids, 5 of which were encountered in the autumn (Lambers, 1971). In the absence of their main primary food plants, these species of aphids can over-winter on the bird cherry and in the spring produce several generations, i.e. the bird cherry contributes to the preservation of these species even in the absence of their main food plants. However, this phenomenon is rather extreme, not massive. This can hardly be considered as a potential attractiveness for ants as a whole, although the number of species far exceeds that found by us. Perhaps the effect of bird cherry on the association of ants is neutral.

Some species of invasive phanerophytes are intensively colonized by aphids. For example, for *Robinia* in Iran, the cosmopolitan species *Aphis craccivora* Koch, 1856 is indicated, visited by the ants *Crematogaster inermis* Mayr, 1862 (Mortazavi *et al.*, 2015). This species of aphids is indicated as an effective agent against the spread of *Robinia* (Jalalipour *et al.*, 2017).

Acer saccharinum can also be inhabited by aphids (*Stomaphis graffii*) and, accordingly, can be visited by ants (*Myrmica rugulosa*, (Depa, 2012)), although the findings of these aphids are rare for Ukraine. Based on our data, *Acer saccharinum* is attractive to aphids and ants. The species of phanerophytes that are not populated by aphids (*Ac. negundo* and others) are unattractive for ants.

Species of aphids and their life cycles on native and invasive phanerophytes

In the greenery of Kyiv on *Acer negundo* in May - early June, small colonies of the European species (1) *Periphyllus testudinaceus* (Ferne, 1852) can be observed. They arise from the dispersal of aphids from native species of maples (*Acer campestre*, *A. platanoides*, *A. pseudoplatanus*, *A. tataricum*) and the introduced species *A. saccharinum*, on which eggs hibernate. In early spring (with warm weather in the third week of March) founders develop from eggs. These colonies are visited by ants, in the spring. But in the beginning of June aphid colonies completely disappear, because *P. testudinaceus* develops with an obligate summer larval diapause and in summer only diapausing larvae (dimorphs) remain on the plants. Sexual generation (morphs) and fundatrices of *P. testudinaceus* on *Acer negundo* were not found and the holocyclic life cycle of aphids was not revealed. *Acer negundo* is probably not suitable for feeding the fundatrices of *P. testudinaceus*.

Robinia pseudoacacia is massively affected by the North American species of aphids, *Aphis craccivora* Koch, 1854. This aphid species was introduced, along with some food plant (probably *R. pseudoacacia*), to Europe, presumably in the 17th century, now cosmopolitan. In most of the range, anholocyclic development occurs, the larvae of *A. craccivora* overwinter on the root parts of herbaceous plants. Data on the development of aphids with a full cycle were also observed, there were reports of hibernating eggs found on the basal parts of alfalfa (*Medicago sativa*), but the sexual generation and founders were not described (Mamontova, 1957). Regardless of the type of life cycle, in May there is active resettlement of plants mainly to plants of the Leguminosae family (2).

At this time, white (*R. pseudoacacia*) and yellow acacia (*Caragana arborescens*) are massively affected by aphids. Aphids are localized on young shoots, inflorescences are colonized during the flowering period, and they are transferred to active growth of young plants.

(1) *Periphyllus testudinaceus* imported to N. America, Australia and New Zealand.

(2) *Aphis craccivora* can colonize plants of other families, most often during a hot period, on the basis of this fact, the species is considered as a polyphage.

Colonies of aphids are massively visited by ants, they can stay on plants until September. According to literary data, *R. pseudoacacia* can also be settled by *Aphis fabae* Scopoli, 1763 (Blackman and Eastop, 1994; Holman, 2009).

The colonies of *A. craccivora* were marked on several plants of *Amorpha fruticosa*, the aphids colonized young shoots; during the flowering period they were localized in inflorescences and passed on to the fruits during their formation and maturation. According to literary data, *A. fruticosa* can also be populated by *Aphis cytisorum* Hartig, 1841 and *A. fabae* Scopoli. (Blackman and Eastop, 1994; Holman, 2009).

Archaeophyte *Salix fragilis* is well populated by native species of aphids. So in the area of our research on this plant, 12 species of aphids were identified, of which 9 are myrmecophilous. *Chaitophorus mordvilko* Mamontova and Szelegiewicz, 1961 and *Ch. truncatus* (Hausmann, 1802) are not visited by ants (Pintera, 1987), and in the colonies of *Ch. niger* Mordvilko, 1929, ants are found sporadically. Aphids of the genus *Cavariella* delGuercio, 1911 (*C. aegopodii* (Scopoli, 1763), *C. archangelicae* (Scopoli, 1763), *C. pastinacae* (Linnaeus, 1758), *C. theobaldi* (Gillette & Bragg, 1918)) develop with heteroecious cycle at the end of May-June migrating to the plants of the family Umbelliferae (Mamontova, 1961). On willows, colonies of aphids along with ants are localized on the lower surface of leaves. The remaining species of aphids are monoecious. *Tuberolachnus salignus* (J.F. Gmelin, 1790) development is anholocyclic, aphids are localized on old shoots, the maximum number is reached in the second half of summer, always visited by ants en masse. Due to an anholocyclic development, the number of aphids in different years strongly depends on the conditions of the winter period and the number of surviving hibernating larvae. In the case of a warm winter, mass outbreaks can be recorded, and in case of strong winter frosts, aphids are practically absent as in the summer. Aphids of the genus *Pterocomma* Buckton, 1879 (*P. pilosum* Buckton, 1879, *P. salicis* (Linnaeus, 1758)) are localized on old shoots, at the base and in cracks in the bark on trunks, often in shelters created by ants, develop strongly throughout the season, but they can greatly influence the number parasites and

predators. *Ch. vitellinae* (Schrank, 1801) inhabits young branches and leaf petioles, develops from spring to autumn, although the number during the season may vary depending on weather conditions and pressure from predators and parasites. *Aphis farinosa* J.F. Gmelin, 1790 forms dense colonies on the bark of young shoots, always with ants. The maximum number is observed in May-June, a facultative shortened life cycle is a characteristic (bisexual generations appear in the beginning of July, at the same time parthenogenetic generation can develop until September). In this regard, the number of aphids drops significantly in the second half of summer, and the species is heavily affected by parasites at this time of the year. The number of species of introduced plants in the green spaces of Kyiv is difficult to estimate, many species are represented by single specimens in botanical gardens and some parks. A number of species are widely introduced into green building and are found everywhere. Of these species, in places where our studies were conducted, *Aesculus hippocastanum*, *Juglans manshurica*, *Padus serotina*, *Acer sacharinum*, *Quercus rubra* are massively represented.

Species of aphids that are trophically confined to the *Aesculus hippocastanum* are not known. However, sometimes during the flowering period, polyphages *A. fabae* and *A. craccivora*, visited by ants, can be observed in the inflorescences. After flowering, aphids completely disappear. According to literary data, maple species of *P. testudinaceus* and *Drepanosiphum platanoidis* (Schrank, 1801) were observed on horse chestnut, which was probably the result of accidental colonization (Blackman and Eastop, 1994; Holman, 2009). In the greenery of Kyiv, these species of aphids on *Aesculus hippocastanum* were never found. *Juglans manshurica* marked adventive colonies of aphids of the species *Panaphis juglandis* (Goeze, 1778), which had long since penetrated, following their forage plant *Juglans regia* probably from initially Asia Minor and Middle Asia into the territory of Ukraine. As a rule, aphids *Panaphis juglandis* live on walnuts; there are few reports of their colonization of manzhur walnut (Holman, 2009). The basis of the food for ants on the Manchurian nut and some other plants not inhabited by aphids can be other sucking insects - coccides and Diaspididae. Aphids are located on the upper surface of the leaves

along the large veins, develop throughout the season, and are actively visited by ants.

The colonies of *Rhopalosiphum padi* (Linnaeus, 1758) are found on *Padus serotina*. This species is currently almost cosmopolitan, in Europe it is usually inhabited by *Padus avium*, in North America it is common on *P. virginiana*, but it is also known on *P. serotina* (Blackman and Eastop, 1994). The species is obligatory heteroecious, host-alternating between bird cherry and many cereals. It starts to develop quite early, the fundatrices can sometimes be found already at the end of March, by the end of April they can reach a considerable number by localizing on young shoots and leaves, after twisting them. They are actively visited by ants. By mid-May, most aphids leave the bird cherry flying onto cereals. By the end of May they migrate completely.

Acer sacharinum is well mastered by native species of aphids. The plant is colonized by European species of aphids: oligophage *P. testudinaceus* which feed on many species of maples, and trophic related with *Acer pseudoplatanus* include aphids like *Periphyllus acericola* (Walker, 1848) and *Drepanosiphum platanoidis* (Schrank, 1801), as well as *Periphyllus lyropictus* (Kessler, 1886). *P. lyropictus* is widespread in Europe on *Acer platanoides*. Aphids, *P. acericola*, as well as *P. testudinaceus*, are characterized by a life cycle with an obligate summer larval diapause. Therefore, from the beginning of June only diapausing larvae (dimorphs) remain on plants. Thus, *P. testudinaceus* and *P. acericola* may affect the attractiveness of *Acer sacharinum* for ants only in spring. Unlike these species, *P. lyropictus* develops without summer diapause and can be observed on the leaves of *Acer sacharinum* throughout the seasons, however, the mass reproduction of aphids occurs usually in June; aphids secrete a lot of honeydew and heavily pollute the plants. *D. platanoidis* reaches numbers at the end of May-June, however, with a cool summer, the peak of numbers may shift by July-August (with a hot summer there is a summer diapause). All species are localized on the lower surface of the leaves, and *P. testudinaceus* is also seen on young shoots (the fundatrices appearing before the leaves bloom are localized on the bark of the shoots of previous year, which indicates the holocyclic development of this species of aphids on *Acer*

sacharinum, unlike *Acer negundo*), *P. lyropictus* can transfer on to young fruits. All species of aphids myrmecophylic.

Until recently, aphids were not recorded on *Quercus rubra* in the study area, but we found significant colonies of *Lachnus roboris* (Linnaeus, 1758), which may indicate a gradual acquisition of red oak by this species of aphids. The literary data on the findings of *L. roboris* on *Quercus rubra* are single (Holman, 2009; Havelka and Stary, 2007), however this species of aphids populates not only *Q. robur*, but also a number of other species of oaks, in particular, previously recorded on the American species *Q. palustris*. Aphids form colonies on the bark of the branches, are massively visited by ants (see below).

Of the native species, *Q. robur* was the most visited by ants, which, not least of all, is associated with a high percentage of aphids-colonized plants. In the region of the study, 8 species of aphids were recorded on this species. Of these, the most attractive to the ants was *L. roboris*. Aphids *Thelaxes dryophila* (Schrank, 1801), *Tuberculatus annulatus* (Hartig, 1841) and to a lesser extent, *Myzocallis castanicola* Baker, 1917 were also regularly visited by ants. Fundatrices of *L. roboris* appeared in April, aphids are placed on the bark of the branches, summer colony number may reach 200 individuals, develop until late autumn. *Th. dryophila* is localized on the shoots of the current year, the underside of the leaves, and later on the pluses of young acorns. The species is characterized by an optional short life cycle, i.e. some of the colonies are ending their development by the beginning of the July and in the second half of the summer the number of aphids is much lower. *T. annulatus* is found on the underside of the leaves; aphids do not form dense colonies, however, during mass reproduction, the larval density (adults are only winged) is very high. From the end of June, the number of aphids can fall significantly due to the possible summer imaginal diapause. *M. castanicola* also lives on the lower surface of leaves (adults are only winged). The species does not form dense colonies, the larvae are located singly near the veins, their numbers and density are usually lower than those of *T. annulatus*, and therefore this species is less attractive to ants. A number of species of aphids are noted only on individual plants, but

in this case their attractiveness for ants contributed. In old parks, a relict species *Stomaphis quercus* (Linnaeus, 1758) was recorded on aged oaks. Aphids inhabit cracks in the bark at the bottom of the trunks in the shelters created by ants. The species is closely related to ants, without which it cannot exist at all, but it is rarely found. *Lachnus pallipes* (Hartig, 1841) is well visited by ants, however it was found only once in the study area. *Tuberculatus borealis* (Krzywicz, 1971) is found on only one plant in small numbers with isolated individuals of ants. *Tuberculatus querceus* (Kaltenbach, 1843) is not attractive for ants because of its small size and solitary lifestyle.

A high percentage of plants inhabited by aphids have been identified for native species *Populus alba*, *P. nigra*, *Salix alba*, *Tilia cordata*, *Acer platanoides*, *Betula pendula*, *Pinus sylvestris*. In the region of the study, *Populus alba* has 3 species of aphids that inhabit it. The most widespread species of aphids is *Chaitophorus populeti* (Panzer, 1801), this meristemophilous species in addition to adult poplar plants, affects their young undergrowth. The phylobiont *Chaitophorus populialbae* (Boyerde Fonscolombe, 1841) was recorded on a smaller number of plants; however, in some poplars (especially young ones) it inhabits at least 2/3 of the total number of leaves on each of the plants. The inhabitant of the bark of the branches *Pterocomma populeum* (Kaltenbach, 1843) occurs sporadically. All species of monoecious, develop throughout the season. There are 4 species of aphids on *P. nigra* (not counting halophores that are inaccessible to ants). The meristophilous species *Chaitophorus nassonowi* Mordvilko, 1894, the philobiont *Chaitophorus leucomelas* Koch, 1854 (except for the fundatrices of last year's bark-living shoots), above mentioned *P. populeum*, and the relict *Stomaphis longirostris* (Fabricius, 1787), are found only in one location on the trunks of several plants. All species are monoecious, develop throughout the season, are actively visited by ants, and *Stomaphis longirostris* will live in the shelters created by ants.

13 species of aphids were found on *Salix alba*. The complex is similar to *Salix fragilis*, except for the absence of the myrmecophilous *Chaitophorus mordvilko* and *Ch. truncatus* on *Salix alba* and the presence

of *Pterocomma rufipes* (Hartig, 1841), *Cavariella cicutae* (Koch, 1854) and found on *Salix alba* plants (in the same habitat as *P. nigra*) a rare species of aphid *Stomaphis longirostris*. All, with the exception of *Ch. niger*, myrmecophylic, their characteristic is given above.

Tilia cordata is populated with one species of aphids – *Eucallipterus tiliae* (Linnaeus, 1758), however, this species inhabits many plants, and allocates a lot of honeydew, strongly polluting the leaves. The largest numbers are in June, later both larval and imaginal summer diapause are possible.

Acer platanoides inhabits 5 species of aphids, *P. testudinaceus* is noted on many plants, *Periphyllus aceris* (Linnaeus, 1761) is common, the species with an obligatory summer diapause, occurs until the first decade of June. *P. lyropictus* develops without a summer diapause; it can produce massive outbreaks in some locations populating 100% of maples; *Periphyllus viridulus* Mamontova, 1955 also develops without summer larvaceous diapause, occurs sporadically. All these species are visited by ants. *Drepanosiphum aceris* Koch, 1855 does not affect the attendance of plants by ants because of its small number.

On *Betula pendula* 11 species of aphids were found, 8 of them affect the attractiveness of birch for ants. These are the species that live on the surface of bark *Symydobius oblongus* (vonHeyden, 1837), and meristemophilous species *Glyphina betulae* (Linnaeus, 1758), phylobionts *Betulaphis brevopilosa* Börner, 1940, *Betulaphis quadrituberculata* (Kaltenbach, 1843), *Calaphis flava* Mordvilko, 1928, *Callipterinella calliptera* (Hartig, 1841), *Callipterinella tuberculata* (vonHeyden, 1837), *Euceraphis punctipennis* (Zetterstedt, 1828). On one plant there can be 5-6 different species of aphids, which ensures their high attractiveness for ants. It should be noted that the population of plants with aphids is the highest in late May-June. Such species as *E. punctipennis*, *C. flava* Mordvilko, *B. brevopilosa*, *B. quadrituberculata* disappear in the second half of June due to imaginal or larval summer diapause. The aphid species *Glyphina betulae*, actively visited by ants is characterized by a shortened life cycle and many colonies of this aphid complete their development by mid-end of June, although in

some plants aphids can be observed until August. Thus, by the middle of summer, the attractiveness of silver birch for ants is provided by *S. oblongus* aphids developing throughout the season (a common species, always with ants), and to a lesser extent, *Call. calliptera*, *Call. tuberculata* (the number of these aphids decreases by the middle of summer). *Clethrobius comes* (Walker, 1848) in its biology is similar to *S. oblongus*, it is visited by ants, however it is found in the study area only once and does not play a large role in the attractiveness of plants for ants. The larvae of *Monaphis antennata* (Kaltenbach, 1843) are single on the leaves of birch trees and are not attractive to ants. In the colonies of *Hamamelistes betulinus* (Horvath, 1896), ants are not marked.

Five species of aphids have been identified on *Pinus sylvestris*. The attractiveness of Scots pine for ants is provided by the common species of aphids *Cinara pinea* (Mordvilko, 1895), *C. pini* (Linnaeus, 1758) and *Schizolachnus pineti* (Fabricius, 1781). The first species lives on the shoots of the current and previous years between the needles, it affects the growth on young pines, the second species is localized on the bark of the older branches, the third one lives on the needles. All species are monoecious, developing throughout the seasons. *Cinara pilosa* (Zetterstedt, 1840) is close to *C. pinea*, but it was found only once in the study region, *Eulachnus agilis* (Kaltenbach, 1843) is not very attractive for ants.

For a number of native species, a noticeably smaller number of plants infested with aphids has been recorded. Thus, *Populus tremula* most commonly affects the attendance of ants by the plants already discussed above; *Ch. populeti*, *Pterocomma tremulae* Börner is much less frequently observed, and *Chaitophorus tremulae* Koch, 1854 does not belong to the myrmophilous species. One species of *Myzocallis carpini* aphids (Koch, 1855) is known on *Carpinus betulus*, this species is often found on plants in ornamental curbs, where it can reach a considerable number. However, on many plants, aphids, if present, are in low numbers. It should also be noted that the adults of this species are only winged, the larvae settle alone near the veins on the underside of the leaves (sometimes with high density), the number of aphids drops from

the second half of June (summer diapause is possible). *Fraxinus excelsior* in green areas of Kyiv has registered *Prociphilus bumeliae* (Schrank, 1801) the species inhabits the shoots of the current and last year, knocking the lower side of the leaves into the nests. The species of aphids is obligate dioecious, migrates to the roots of fir (*Abies*) no later than the first ten days of June, and sometimes occurs in parks where there are fir trees. In recent years, a monoecious adventive species of North American origin *Prociphilus fraxinifolii* (Riley, 1879) has been observed in green plantations, introduced together with *Fraxinus pennsylvanica* used in green building. At the same time, in ash trees with high aphid colonies were noticed. *Sambucus nigra* is populated by one species of aphids *Aphis sambuci* Linnaeus, 1758, the species is found sporadically, but forms powerful colonies of a large number of individuals, it is massively visited by ants. The species is facultative dioecious, migrates to the roots of *Rumex* spp., *Lychnis* spp., However, part of the colonies may be placed on young elderberry.

On *Ulmus laevis* (except gall formers, inaccessible to ants), *Tinocallis platani* (Kaltenbach, 1843) is noted, the species populates the lower surface of the leaves, sometimes young shoots. On some young plants they can reach a significant number, highly polluting the plants.

On some natural plants, aphids were not found at the collection points of this study, which may be due to the small number of plants we examined. But in the study area, aphids on these plants were reported (Zhuravlev, 2005). So on *Padus avium* notes *Rhopalosiphum padi* described above, on *Ulmus glabra* – *Tinocallis platani*, on *Acer campestre* – *P. testudinaceus*, developing without summer diapause, *Periphyllus obscurus* Mamontova, 1955, and a rather rare obligate, dioecious species migrating to elm roots, *Mimeuria ulmiphila* (delGuercio, 1917). *Euonymus verrucosus* is one of the primary food plants of the aphids of the *Aphis fabae* group (*Aphis fabae* Scopoli, 1763; *Aphis euonymi* Fabricius, 1775; *Aphis cirsiiacanthoidis* Scopoli, 1763; *Aphis solanella* Theobald, 1914), however, we note that these species are more often populated with *Euonymus europaeus*. On *Pyrus communis* we observed 5 species (*Melanaphis pyrararia* (Passerini, 1861); *Rhopalosiphum*

insertum (Walker, 1849); *Anuraphis farfarae* (Koch, 1854); *Anuraphis subterranea* (Walker, 1852); *Dysaphis pyri* (Boyerde Fonscolombe, 1841)). All these species of aphids are rare and have an obligate dioecious life cycle; therefore they can be observed on a *Pyrus communis* only until mid-June.

Conclusions

For Kyiv, 59 species of ants are known, belonging to 22 genera and 4 subfamilies (Radchenko *et al.*, 2019). Of these, for forests and parks, the authors cite 27 species of ants. This practically corresponds to the number of ant species we found in the studied habitats (21 species, 3 subfamilies). Consequently, arboreal and shrubby vegetation is fairly well visited by most ant species (in the region under study). The reasons for such a visit were established by us - these are nesting places and the presence of colonies of myrmecophilous aphids. Among the myrmecofauna of Kyiv, invasive ant species are also known - 4 of them were found (Radchenko *et al.*, 2019). These species were not included in our study, since 3 of them live in heated premises (greenhouses etc.). An exception was one species, *Lasius neglectus* Van Loon *et al.*, 1990, found on the territory of public gardens in the central part of Kyiv (Radchenko *et al.*, 2019).

The fauna of dendrophilous aphids in the green spaces of Kyiv numbers 176 species (Zhuravlev, 2005). Of the species found here on the examined plants, only *Aphis crassivora* and *Panaphis juglandis* can be considered as adventive species. Among the dendrophilous aphid species common in Kyiv and its environs at the moment, at least 35 (19.8% of the total number of aphid species in Kyiv) are adventive. Moreover, 17 of them are trophically related to gymnosperms, which were introduced for green building. The origin of a number of aphid species is unknown. Of the aphids inhabiting invasive and introduced plant species, 2/3 of the species are native species, and 1/3 are adventive. Usually, introduced plants are assimilated by native species of oligophagous aphids, trophically associated with representatives of the same or phylogenetically close genera of plants of the native flora. For example, the North American maple species *Acer sacharinum* is inhabited by aphids trophically related to the European maple species *A. platanoides* (species of

aphids *Periphyllus lyropictus* (Kessler, 1886), *P. testudinaceus* (Ferne, 1852)) and *A. pseudoplatanus* (species of aphids *Drepanosiphum platanoides* (Schrank, 1801), *Periphyllus acericola* (Walker, 1848), *P. testudinaceus*). This example demonstrates the possibility of colonization by aphids of introduced plants originating from outside their original range, if they belong to the same genus as the original food plants of the aphids. Apparently, this possibility depends on the biochemical composition of the plant sap and the presence of enzymes in aphids that can assimilate it. This article also provides a case of colonization of the North American oak species *Quercus rubra* L. by the European species of the aphid *Lachnus roboris* (Linnaeus, 1758). However, the range of dendrophilic oligophagous aphid species is often very wide and in different parts of the range they can feed on various plant species of the same genus. Thus, the Far Eastern populations of the Trans-Palaeartic aphid species *Callipterinella calliptera* (Hartig, 1841) inhabit *Betula mandshurica* (Regel) Nakai and *B. dahurica* Pall., and the European populations on *Betula pendula*, therefore, when Far Eastern birch species are introduced to Ukraine, the aboriginal populations of *C. calliptera* successfully master them. This may also be associated with a significant diversity of aphid species on *Salix fragilis*. At least some of this aphid species inhabiting the willow have wide ranges (Holarctic, Trans-Palaeartic, or Euro-Siberian). This wide range of aphid species apparently including the original range of *S. fragilis*. Possibly, that the *S. fragilis* was invaded by many aphids species, because the *Salix fragilis* is an archeophyte in Ukraine. This also may be the reason for the large species diversity of aphids on the *S. fragilis* and, as a consequence, its attractiveness for ants.

On the other hand, the invasive North American maple *Acer negundo* in the study region is inhabited by only one species of aphid *P. testudinaceus*. Colonies of aphids on this plant are not large and not persistent, probably still, in terms of its biochemical characteristics; this maple is not quite suitable for this type of aphid. In the fauna of Ukraine there are no species of aphids living on maples with Holarctic ranges (some species of aphids were brought to North America), including the original range of *Acer negundo*. In addition,

this species of maple belongs to the kenophytes i.e. its invasion occurred relatively recently. Therefore, *Acer negundo* is partially mastered by only one species of aphids, which possesses the widest range of food plants of all European species of aphids living on maples. Hence, the attractiveness of *Acer negundo* to ants remains extremely low.

Thus, the possibility of developing a new ecological niche provided by introduced and invasive plant species to native species of ants and aphids exists and depends on a) the biochemical correspondence of the plant sap and aphid enzymes, b) the correspondence of the aphid range with the initial range of the introduced plant, c) the time of plant species invasion. Probably, depending on the age of the plant invasion, its gradual colonization by local aphid species is observed, and, further, the increasing attractiveness of this plant species for visiting by ants.

Due to the narrow trophic specialization of aphids, introduced plants that do not have phylogenetic closely related forms in the flora of Ukraine are practically not inhabited by aboriginal aphids (except for the polyphage *Aphis fabae* Scopoli). However, they can be damaged by trophically specialized adventive species that penetrate into new territories following their food plant. For example, plant species *Catalpa bignonioides* Walt. inhabited by aphid species *Aphis catalpae* Mamontova, plant *Juglans regia* L. – by aphids *Chromaphis juglandicola* Kaltenbach and *Panaphis juglandis* Goeze. Among herbaceous plants on the territory of Kyiv, such an example is plant species *Impatiens parviflora* DC. and the related aphid species *Impatiensium asiaticum* Nevsky (Stukalyuk, 2016). If, along with such a plant, the invasion of trophically related aphid species does not occur, then in new territories these plants remain unattractive for aphids and, as a consequence, for ants.

At the moment, most of the invasive phanerophyte plant species are not attractive to ants and aphids (in the studied Kyiv region). However, native species of aphids and ants are able to form stable trophic relations with certain invasive species of both phanerophytes and herbaceous plants, for example, *Heracleum mantegazzianum* Manden, *Onopordum acanthium* L., *Asclepias syriaca* L., *Oenothera biennis* L. (Stukalyuk *et al.*, 2019) from the same area. It is noteworthy that

of these herbaceous plant species, the archeophyte species (*Onopordum acanthium*) was the most visited by ants and was also affected by aphids, which, in this case, may be due to the age of invasion of the plant species, which predetermined the population of aphids and the attractiveness of the plant for ants.

More than 1600 plant species are known from the territory of Kyiv city and the region, of which no more than 95 species are invasive, 5.9% of all plant species) (Yavorska, 2002; Protopopova *et al.*, 2009; Grechyshkina, 2010). Among the total number of plant species in the territory of Kyiv, 182 species are phanerophytes, which is 11.3% of their total number (Pikhalo, 2011). Of the 1647 plant species in Moscow, about 10% are invasive (Shcherbakov and Lyubeznova, 2018). There are 146 known phanerophytes, or 8.8% of the total number of vascular plant species in Moscow (Yakushina, 1969; Shcherbakov and Lyubeznova, 2018).

The flora of the Czech Republic numbers 4360 species and subspecies of vascular plants, of which 1454 are adventive. Among them, 61 (4.2%) are invasive species (Pyšek *et al.*, 2012). The flora of Zagreb (Croatia) includes 351 species of vascular plants, among which 22 species or 6.26% are invasive (Hudina *et al.*, 2012). Flora of Rome has 1649 species, 186 of which are neophytes. Unfortunately, in the list of species submitted in the article, the authors do not indicate the number of invasive ones, and they are not marked in the list itself, but based on materials from other cities, they should not exceed 5-10% of the total number of species (Celesti-Grapow *et al.*, 2013).

Thus, large cities are places of primary appearance of new invasive plant species in the secondary range. Further, these plant species can very successfully spread to neighboring territories. This spread leads to the gradual displacement of native plant species or to a decrease in their number. Then there is their gradual replacement in native phytocenoses. And this leads to a decrease in the natural coenotic diversity, which can subsequently lead to the impoverishment of communities, their uniformity, deterioration of the structure of the herbage, and a decrease in tiering.

Currently, in the green spaces of cities, and especially in botanical gardens, there are a greater number of invasive plant species that

could potentially be assimilated by local species of aphids and ants. At the same time, invasive plant species are more often colonized by native aphid species and visited by native ant species. Thus, in urban conditions, invasive plant species can more quickly, in comparison with natural habitats, be assimilated by local aphid species and become attractive to local ant species.

Acknowledgements

The authors are grateful to Prof. W. Czechowski (Polish Academy of Sciences, Museum and Institute of Zoology) for valuable advice and comments.

References

- Aerts, R., Ewald, M., Nicolas, M., Piat, J., Skowronek, S., Lenoir, J., Hattab, T., Garzón-López, C.X., Feilhauer, H., Schmidtlein, S., Rocchini, D., Decocq, G., Somers, B., Van De Kerchove, R., Deneff, K. and Honnay, O. 2017. Invasion by the Alien Tree *Prunus serotina* Alters Ecosystem Functions in a Temperate Deciduous Forest. *Frontiers in Plant Science* 8: 1–11.
- Alloway, T.M. and Hodgson S. 1990. Nest recognition in the ant, *Leptothorax ambiguus* Emery (Hymenoptera: Formicidae). *Psyche A Journal of Entomology* 97(3-4): 175–180.
- Blackman, R.L. and Eastop, V.F. 1994. Aphids on the world's trees. London: CABI. 1017 pp.
- Burda, R.I., Pashkevich, N.A., Blinkova, O.I., Shupova, T.V., Stukalyuk, S.V., Ivanenko, O.M. and Bilushenko, A.A. 2018. Adaptive strategy of populations of alien species. Kyiv: Naukova Dumka, 192 p.
- Buchholz, S., Tietze, H., Kowarik, I. and Schirmer, J. 2015. Effects of a Major Tree Invader on Urban Woodland Arthropods. *PLOS ONE* 10(9): e0137723. DOI:10.1371/journal.pone.0137723.
- Celesti-Grapow, L., Capotorti, G., Del Vico, E., Lattanzi, E., Tilia, A. and Blasi, C. 2013. The vascular flora of Rome. *Plant Biosystems - An International Journal Dealing with all Aspects of Plant Biology* 147(4): 1059–1087. DOI: 10.1080/11263504.2013.862315
- Chmura, D. 2013. Impact of alien tree species *Quercus rubra* L. on understory environment and flora. A study of the Silesian Upland (Southern Poland). *Polish Journal of Ecology* 61(3): 431–442.
- Csóka, G. 1998. Herbivore insect guild of oaks in Hungary. *Forestry researches*. 88: 311–318. (in Hungarian).
- Csóka, G. and Hirka, A. 2002. Adatok a Magyarországon nem őshonos tölgyeken megtelepedő herbivor rovarok ismeretéhez (Data to knowledge of herbivore insects colonizing exotic oaks in Hungary). *Proceedings of the Forest Research Institute* 90: 195–204. (in Hungarian with English abstract).
- Czechowski, W., Czechowska, W. and Palmowska, J. 1990. Arboreal myrmecofauna of Warsaw parks. *Fragmenta Faunistica* 37–45.
- Depa, L. 2012. Abundance of *Stomaphis graffiti* Cholod. (Hemiptera) on maple trees in Poland. *Open Life Sciences* 7(2): 284–287.
- Didukh, J.P. and Aloskina, V.M. 2012. Biotopes of the city of Kyiv. Kyiv: NaUKMA, Agrar Media Group, 163 p.
- Dray, S., Pavoine, S. and Aguirre de Carcer, D. 2015. Considering external information to improve the phylogenetic comparison of microbial communities: a new approach based on constrained Double Principal Coordinates Analysis (cDPCoA). *Molecular Ecology Resources* 15: 242–249. doi:10.1111/1755-0998.12300
- Dzwonko, Z. and Loster, S. 1997. Effects of dominant trees and anthropogenic disturbances on species richness and floristic composition of secondary communities in southern Poland. *Journal of Applied Ecology* 34: 861–870.
- European Nature Information System –EUNIS database. <https://eunis.eea.europa.eu/> accessed on 12.10.2020.
- Godefroid, S., Phartya, S.S., Weyembergh G. and Koedam, N. 2005. Ecological factors controlling the abundance of non-native invasive black cherry (*Prunus serotina*) in deciduous forest understory in Belgium. *Forest Ecology and Management* 210: 91–105.
- Grechyshkina, Yu. V. 2010. The Native Flora of Kyiv City. – Manuscript. The thesis for the degree of the candidate of the biological sciences (PhD), specialty 03.00.05 – Botany. M.G. Kholodny

- Institute of Botany of the National Academy of Sciences of Ukraine, Kyiv, 25 p. [In Ukrainian].
- Grześ, I.M., Ślipiński, P., Babik, H., Moroń, D., Walter, B., Trigos-Peral, G., Maak, I. and Witek, M. 2018. Colony size and brood investment of *Myrmica rubra* ant colonies in habitats invaded by goldenrods. *Insectes Sociaux* 1–6. <https://doi.org/10.1007/s00040-018-0612-0>
- Havelka, J. and Stary P. 2007. *Myzocallis walshii* (Hemiptera: Sternorrhyncha: Aphididae), an exotic invasive aphid on *Quercus rubra*, the American red oak: Its bionomy in the Czech Republic. *European Journal of Entomology* 104: 471–477.
- Holldobler, B. and Wilson E.O. 1990. *The Ants*. Berlin: Springer. 732 pp.
- Holman, J. 2009. *Host Plant Catalog of Aphids Palearctic Region*. Springer. 1216 p.
- Hudina, T., Salkić, B., Rimac, A., Bogdanović, S. and Nikolić, T. 2012. Contribution to the urban flora of Zagreb (Croatia). *Natura Croatica : Periodicum Musei Historiae Naturalis Croatici* 21(2): 357–372.
- Jalalipour, R., Sahragard, A., Madahi, Kh. and Karimi-Malati, A. 2017. Comparative life table of *Aphis craccivora* (Hem.: Aphididae) on host plant, *Robinia pseudoacacia* under natural and laboratory conditions. *Journal of Entomological Society of Iran* 36(4): 249–257.
- Lambers, D.H.R. 1971. *Prunus serotina* (American bird-cherry) as a host plant of Aphididae in the Netherlands. *Netherlands Journal of Plant Pathology* 77: 140–143.
- Lenda, M., Witek, M., Skořka, P., Moron', D. and Woyciechowski, M. 2013. Invasive alien plants affect grassland ant communities, colony size and foraging behavior. *Biological Invasions* 15: 2403–2414.
- Mamontova, V.A. 1957. About the role of white and yellow acacia in the reserve of alfalfa aphids *Aphis medicaginis* Koch. *Collection of works of the Zoological Museum* 28: 91–99. (in Ukrainian).
- Mamontova, V.A. 1961. Aphids of the genus *Cavariella* Guer. (Homoptera, Aphidoidea) in the USSR. *Proceedings of the Zoology Institute of the Academy of Sciences of the USSR* 27: 54–65. (in Ukrainian).
- Mortazavi, Z.S., Sadeghi, H., Aktac, N., Depa, Ł. and Fekrat L. 2015. Ants (Hymenoptera: Formicidae) and their aphid partners (Homoptera: Aphididae) in Mashhad region, Razavi Khorasan Province, with new records of aphids and ant species for Fauna of Iran. *Halteres* 6: 4–12.
- Mosyakin, S.L. and Yavorska, O.G. 2002. The Nonnative Flora of the Kiev (Kyiv) Urban Area, Ukraine: A Checklist and Brief Analysis Urban habitats 1(1). ISSN 1541-7115.
- Myczko, Ł., Dylewski, Ł., Mitrus, Sł. and Sparks, T.H. 2018. Invasive Northern Red Oaks benefit *Temnothorax crassispinus* (Hymenoptera: Formicidae) ant colonies. *Myrmecological News* 27: 25–31.
- Nentwig, W., Bacher, S., Kumschick, S., Pysek, P. and Vila M. 2017. More than 100 worst alien species in Europe. *Biological Invasions* 20(6): 1611–1621.
- Pikhalo, O. 2011. Biological and ecological features of street plantings growth in Kyiv historical part. – The manuscript. The dissertation for awarding a scientific degree of candidate of agricultural sciences candidate on specialty 06.03.01 – forestry plantations and phytomelioration. – National University of Life and Environmental Sciences of Ukraine of Cabinet of Ministers of Ukraine. – Kyiv, – 23 pp. [In Ukrainian].
- Pintera, A. 1987. Taxonomic revision of the species of genus *Chaitophorus* Kochin Palearktis (Homoptera: Aphidoidea). *Deutsche entomologische Zeitschrift* 34(4–5): 219–340.
- Popov, V.P., Marynich, A.M., Lanko, A.I. 1968. (eds.) *Physical and geographical regionalization of the Ukrainian SSR*. Kiev: Publishing House of Kiev University, 683 pp.
- Protopopova, V.V., Shevera, M.V., Mosyakin, S.L., Solomakha, V.A., Solomakha, T.D., Vasil'eva, T.V. and Petrik, S.P. 2009. *Invasive Plants in the Flora of the Northern Black Sea Region*. Kyiv: Phytosociocentre, 56 pp. [in Ukrainian].
- Protopopova, V.V., Shevera, M.V., Fedoronchuk, M.M. and Shevchik, V.L., 2014. *Transformer Species in the Flora of*

- the Middle Dnipro Region. Ukrainian Botanical Journal 71(5): 563–572.
- Pyšek, P., Chytrý, M., Pergl, J., Sádlo, J. and Wild, J. 2012. Plant invasions in the Czech Republic: current state, introduction dynamics, invasive species and invaded habitats. Preslia 84: 575–629.
- Radchenko, A.G. 2016. Ants (Hymenoptera, Formicidae) of Ukraine. Kyiv: Institute of Zoology, 496 p. [in Russian].
- Radchenko, A.G., Stukalyuk, S.V. and Netsvetov M.V. 2019. Ants (Hymenoptera, Formicidae) of Kyiv. Entomological Review 99(6): 753–773. DOI: 10.1134/S0013873819060058
- Raunkiaer, C. 1905. Types biologiques pour la géographie botanique. Oversigt over Det Kongelige Danske Videnskabernes Selskabs Forhandlinger 347–438.
- Richardson, D.M. and Rejmanek, M. 2011. Trees and shrubs as invasive alien species – a global review. Diversity and Distributions 17: 788–809.
- Roy, D., Alderman, D., Anastasiu, P., Arianoutsou, M., Augustin, S., Bacher, S., Başnou, C., Beisel, J., Bertolino, S., Bonesi, L., Bretagnolle, F., Chapuis, J.L., Chauvel, B., Chiron, F., Clergeau, P., Cooper, J., Cunha, T., Delipetrou, P., Desprez-Loustau, M., Détaint, M., Devin, S., Didžiulis, V., Essl, F., Galil, B.S., Genovesi, P., Gherardi, F., Gollasch, S., Hejda, M., Hulme, P.E., Josefsson, M., Kark, S., Kauhala, K., Kenis, M., Klotz, S., Kobelt, M., Kühn, I., Lambdon, P.W., Larsson, T., Lopez-Vaamonde, C., Lorvelec, O., Marchante, H., Minchin, D., Nentwig, W., Occhipinti-Ambrogi, A., Olenin, S., Olenina, I., Ovcharenko, I., Panov, V.E., Pascal, M., Pergl, J., Perglová, I., Pino, J., Pyšek, P., Rabitsch, W., Rasplus, J., Rathod, B., Roques, A., Roy, H., Sauvard, D., Scalera, R., Shiganova, T.A., Shirley, S., Shwartz, A., Solarz, W., Vilà, M., Winter, M., Yésou, P., Zaiko, A., Adriaens, T., Desmet, P. and Reyserhove, L. 2020. DAISIE - Inventory of alien invasive species in Europe. Version 1.7. Research Institute for Nature and Forest (INBO). Checklist dataset <https://doi.org/10.15468/ybwd3x> accessed on 10.10.2020.
- Shapiro, S.S. and Wilk, M.B. 1965. An analysis of variance test for normality (complete samples). Biometrika 52: 591–611.
- Shcherbakov, A.V. and Lyubeznova, N.V. 2018. List of vascular plants of the Moscow flora. - Moscow: Galley-Print LLC. 160 p. [In Russian].
- Stukalyuk, S.V. 2016. Changes in the Structure of Ant Assemblages in Broad-Leaved Forests with Domination of *Impatiens parviflora* Dc. (Balsaminaceae) in Herbaceous Layer. Russian Journal of Biological Invasions 7(4): 383–395.
- Stukalyuk, S.V., Zhuravlev, V.V., Netsvetov M.V. and Kozyr, M.S. 2019. Effect of invasive species of herbaceous plants and associated aphids (Hemiptera, Sternorrhyncha: Aphididae) on the structure of ant assemblages (Hymenoptera, Formicidae). Entomological Review 99: 711–732. <https://doi.org/10.1134/S0013873819060022>
- Ter Braak, C.J.F. 1986. Canonical Correspondence Analysis: A New Eigenvector Technique for Multivariate Direct Gradient Analysis. Ecology 67(5): 1167–1179. doi:10.2307/1938672
- Tokarska-Guzik, B. 2005. Invasive ability of kenophytes occurring in Poland: a tentative assessment. Neobiota 6: 47–65.
- Trigos-Peral, G., Casacci, L.P., Ślipiński, P., Grześ, I.M., Moroń, D., Babik, H. and Witek, M. 2018. Ant communities and *Solidago* plant invasion: Environmental properties and food sources. Entomological Science 1–9. doi: 10.1111/ens.12304
- Vítková, M., Müllerová, J., Sádlo, J., Pergl, J. and Pyšek, P. 2017. Black locust (*Robinia pseudoacacia*) beloved and despised: A story of an invasive tree in Central Europe. Forest Ecology and Management 384: 287–302.
- Weiss, J., Burghardt, W., Gausmann, P., Haag, R., Haeupler, H., Hamann, M., Leder, B., Schulte, A. and Stempelmann, I. 2005. Nature Returns to Abandoned Industrial Land: Monitoring Succession in Urban-Industrial Woodlands in the German Ruhr. Wild Urban Woodlands 143–162.
- Wilson, E O. 1990. Success and Dominance in Ecosystems. The case of Social Insects. Oldendorf/Luhe: International Ecology Institute 104 pp.

- Yakushina, E. I. 1969. Trees and bushes in gardens and parks of Moscow. Bulletin of the Main Botanical Garden of the USSR Academy of Sciences 74: 14-21. [In Russian].
- Yavorska, O.G. 2002. The alien fraction of the synanthropic flora of the Kyiv urban area. – Manuscript. Thesis for the candidate's degree by speciality 03.00.05 – botany – M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine, Kyiv, 23 p. [In Ukrainian].
- Zakharov, A.A. 1991. Organization of Ant Communities. Moscow: Nauka. 276 pp.
- Zhuravlev, V.V. 2005. Aphids (Homoptera, Aphidoidea) of the arboreal-fruticose vegetation of Ukraine: dissertation abstract for the degree of candidate of biological sciences; National Academy of Sciences of Ukraine, Schmalhausen Institute of Zoology, National Academy of Sciences of Ukraine. - Kyiv - 23 p. [In Ukrainian].

Supplementary Tables**Table 1. Average number of ants / 2 min in habitats on different tree species**

Habitat/ Species of plants	G1.A162	X11	G5.1	G1.A5	G4.F	E2.1	G5.2	G1.11	G1.C2	X
<i>Quercus robur</i>	23.61 ± 3.47	17.45 ± 2.26	7.43 ± 1.43	13.93± 4.05	0	0	0	20.08 ± 4.61	0	16.4
<i>Acer platanoides</i>	6.77 ± 0.95	14.35 ± 1.56	15.11 ± 2.73	0	0	0	0	0	0	12.0
<i>Acer platanoides</i> saplings	3.59 ± 0.43	0	0	0	0	0	0	0	0	3.6
<i>Carpinus betulus</i>	1.86 ± 0.40	0	0	0	0	0	0	0	0	1.8
<i>Fraxinus excelsior</i>	1.93 ± 0.81	5.32 ± 2.64	2.42 ± 1.14	0	0	0	0	0	0	3.2
<i>Euonymus verrucosus</i>	0.22 ± 0.07	0	0	0	0	0	0	0	0	0.2
<i>Ulmus glabra</i>	0.62 ± 0.10	0	0	0	0	0	0	0	0	0.6
<i>Ulmus laevis</i>	0	0	2.64 ± 0.82	0	0	0	0	2.36 ± 1.32	0	2.6
<i>Salix nigra</i>	1.00 ± 0.17	0.1 ± 0.1	0	2.03 ± 0.26	0	0	0	0	0	1
<i>Robinia pseudoacacia</i>	0	5.07 ± 0.94	5.47 ± 0.82	0	0.48 ± 0.11	1.40 ± 0.46	3.72 ± 1.06	0	0	3.2
<i>Populus alba</i>	0	16.08 ± 2.53	8.52 ± 1.90	0	0	2.85 ± 0.54	0	6.61 ± 1.32 2.02 ± 0.67 (\$)	0	7.2
<i>Tilia cordata</i>	0	5.95 ± 0.59	12.72 ± 1.22	4.13 ± 1.35	0	0	0	0	0	7.6
<i>Betula pendula</i>	0	15.5 ± 2.16	8.17 ± 0.77	0	2.50 ± 2.36	0	0	0	0	8.7
<i>Populus nigra</i>	0	12.24 ± 1.42	3.94 ± 0.41	0	0	0.03 ± 0.02 (\$)	0	1.98 ± 0.55	0	6.0
<i>Juglans mandshurica</i>	0	3.42 ± 1.47	14.5 ± 4.64	0	0	0	0	0	0	8.9
<i>Aesculus hippocastanum</i>	0	3.17 ± 0.76	2.9 ± 1.84	0	0	0	0	0	0	3.0
<i>Acer saccharinum</i>	0	2.64 ± 0.73	4.3 ± 0.37	0	0	0	0	0	0	3.4
<i>Quercus rubra</i>	0	7.62 ± 1.25	10.95 ± 1.4	0	0	0	0	0	4.67 ± 0.74 1.00 ± 0.11 (\$) 1.70 ± 0.29 (\$)	7.7
<i>Pinus sylvestris</i>	0	7.88 ± 1.12	0	0	9.54 ± 1.96	0	0	0	0	8.7
<i>Amorpha fruticosa</i>	0	0	0	0	0.04 ± 0.01	0	0	0.02 ± 0.01	0	0.02

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<i>Padus serotina</i>	0	0	0	0	0.45 ± 0.07	0	0	0	0	0.22
<i>Padus avium</i>	0	0	0	0	0.03 ± 0.01	0	0	0	0	0.03
<i>Salix fragilis</i>	0	0	13.63 ± 2.23	0	0	0	0	2.71 ± 0.78 0 ± 0(\$)	0	8.1
<i>Acer negundo</i>	0	0	0.50 ± 0.15	0	0	0	0	0.24 ± 0.10	0	0.25
<i>Acer negundo</i> saplings	0	0	0.006 ± 0.006	0	0	0	0	0	0	0.006
<i>Pyrus communis</i>	0	0	2.06 ± 0.72	0	0	0	0	0	0	2.1
<i>Populus tremula</i>	0	0	7.12 ± 3.13	0	0	0	0	4.60 ± 1.69	0	5.8
<i>Salix alba</i>	0	0	13.41 ± 7.61	0	0	0	0	0	0	13.4
<i>Acer campestre</i>	0	0	0	0	0	0	0	0	0.56 ± 0.20	0.6

(Note: \$- saplings)

Table 2. List of aphid and ant species on invasive and native plants

Invasive plant species	Aphid species	Ant species
<i>Acer negundo</i>	<i>Periphyllus testudinaceus</i> (Ferne, 1852)	<i>Formica cinerea</i> , <i>Lasius emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>L. umbratus</i>
<i>Robinia pseudoacacia</i>	<i>Aphis craccivora</i> Koch, 1854	<i>Camponotus fallax</i> , <i>C. vagus</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>F. polycheta</i> , <i>F. rufibarbis</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>L. platythorax</i> , <i>Temnothorax</i> sp.
<i>Amorpha fruticosa</i>	<i>Aphis craccivora</i> Koch, 1854	<i>Formica cinerea</i> , <i>Lasius niger</i> , <i>L. platythorax</i>
<i>Salix fragilis</i>	<i>Aphis farinosa</i> J. F. Gmelin, 1790, <i>Tuberolachnus salignus</i> (J. F. Gmelin, 1790), <i>Cavariella aegopodii</i> (Scopoli, 1763)	<i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>Lasius fuliginosus</i> , <i>L. niger</i>
<i>Juglans mandshurica</i>	<i>Panaphis juglandis</i> (Goeze, 1778)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. niger</i> , <i>Temnothorax</i> sp.
<i>Padus serotina</i>	<i>Rhopalosiphum padi</i> (Linnaeus, 1758)	<i>Camponotus vagus</i> , <i>Formica cinerea</i> , <i>F. fusca</i> , <i>Lasius platythorax</i> , <i>Leptothorax</i> sp., <i>Myrmica</i> sp., <i>Temnothorax</i> sp.
<i>Acer sacharinum</i>	<i>Periphyllus testudinaceus</i> (Ferne, 1852), <i>Periphyllus acericola</i> (Walker, 1848), <i>Periphyllus lyropictus</i> (Kessler, 1886), <i>Drepanosiphum platanoidis</i> (Schrank, 1801)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>Myrmica</i> sp.

<i>Quercus rubra</i>	<i>Lachnus roboris</i> (Linnaeus, 1758)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>F. rufibarbis</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>Myrmica</i> sp., <i>Temnothorax</i> sp.
<i>Aesculus hippocastanum</i>	<i>Aphis fabae</i> Scopoli, 1763	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. niger</i> , <i>Temnothorax</i> sp.
Native plant species	Aphid species	Ant species
<i>Quercus robur</i>	<i>Lachnus roboris</i> (Linnaeus, 1758), <i>Lachnus pallipes</i> (Hartig, 1841), <i>Thelaxes dryophila</i> (Schrank, 1801), <i>Tuberculatus annulatus</i> (Hartig, 1841), <i>Myzocallis castanicola</i> Baker, 1917, <i>Stomaphis quercus</i> (Linnaeus, 1758)	<i>Camponotus fallax</i> , <i>C. ligniperdus</i> , <i>C. vagus</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>F. cunicularia</i> , <i>F. fusca</i> , <i>F. rufa</i> , <i>F. rufibarbis</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>L. platythorax</i> , <i>L. umbratus</i> , <i>Myrmica</i> sp., <i>Temnothorax</i> sp.
<i>Populus alba</i>	<i>Chaitophorus populeti</i> (Panzer, 1801), <i>Chaitophorus populialbae</i> (Boyer de Fonscolombe, 1841), <i>Pterocomma populeum</i> (Kaltenbach, 1843)	<i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>F. rufibarbis</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>Myrmica</i> sp.
<i>Salix babylonica</i>	<i>Aphis farinosa</i> J. F. Gmelin, 1790, <i>Chaitophorus vitellinae</i> (Schrank, 1801), <i>Pterocomma. Pilosum</i> Buckton, 1879, <i>Pterocomma salicis</i> (Linnaeus, 1758), <i>Pterocomma rufipes</i> (Hartig, 1841), <i>Cavariella. aegopodii</i> (Scopoli, 1763), <i>Cavariella archangelicae</i> (Scopoli, 1763), <i>Cavariella pastinacae</i> (Linnaeus, 1758), <i>Cavariella theobaldi</i> (Gillette & Bragg, 1918), <i>Stomaphis longirostris</i> (Fabricius, 1787)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Lasius brunneus</i> , <i>L. fuliginosus</i> , <i>L. niger</i>
<i>Populus nigra</i> (not counting inaccessible for ant halophores)	<i>Chaitophorus nassonowi</i> Mordvilko, 1894, <i>Chaitophorus leucomelas</i> Koch, 1854, <i>Pterocomma populeum</i> (Kaltenbach, 1843), <i>Stomaphis longirostris</i> (Fabricius, 1787)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>F. rufibarbis</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i>
<i>Tilia cordata</i>	<i>Eucallipterus tiliae</i> (Linnaeus, 1758)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>F. rufibarbis</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. niger</i> , <i>Myrmica</i> sp.
<i>Acer platanoides</i>	<i>Periphyllus testudinaceus</i> (Ferne, 1852), <i>Periphyllus aceris</i> (Linnaeus, 1761),	<i>Camponotus fallax</i> , <i>C. ligniperdus</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>F. cunicularia</i> , <i>F. fusca</i> , <i>F. rufa</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L.</i>

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	<i>Periphyllus lyropictus</i> (Kessler, 1886), <i>Periphyllus coracinus</i> (Koch, C.L., 1854)(= <i>Periphyllus viridulus</i> Mamontova, 1955)	<i>fuliginosus</i> , <i>L. niger</i> , <i>L. platythorax</i> , <i>Myrmica</i> sp., <i>Temnothorax</i> sp.
<i>Betula pendula</i>	<i>Symydobius oblongus</i> (von Heyden, 1837), <i>Glyphina betulae</i> (Linnaeus, 1758), <i>Callipterinella calliptera</i> (Hartig, 1841), <i>Callipterinella tuberculata</i> (von Heyden, 1837), <i>Euceraphis punctipennis</i> (Zetterstedt, 1828), <i>Betulaphis brevopilosa</i> Börner, 1940, <i>Betulaphis quadrituberculata</i> (Kaltenbach, 1843), <i>Calaphis flava</i> Mordvilko, 1928, <i>Clethrobis comes</i> (Walker, 1848)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>Lasius emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>L. platythorax</i> , <i>Temnothorax</i> sp.
<i>Populus tremula</i>	<i>Chaitophorus populeti</i> (Panzer, 1801), <i>Pterocomma tremulae</i> Börner, 1940	<i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>L. fuliginosus</i> , <i>L. niger</i>
<i>Carpinus betulus</i>	<i>Myzocallis carpini</i> (Koch, 1855)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica fusca</i> , <i>F. rufa</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. platythorax</i> , <i>Myrmica</i> sp.
<i>Sambucus nigra</i>	<i>Aphis sambuci</i> Linnaeus, 1758	<i>Lasius emarginatus</i> , <i>L. niger</i> , <i>L. platythorax</i> , <i>Leptothorax</i> sp., <i>Myrmica</i> sp., <i>Temnothorax</i> sp.
<i>Fraxinus excelsior</i>	<i>Prociphilus bumeliae</i> (Schrank, 1801)	<i>Camponotus fallax</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>Myrmica</i> sp.
<i>Pinus sylvestris</i>	<i>Cinara pinea</i> (Mordvilko, 1895), <i>Cinara pilosa</i> (Zetterstedt, 1840), <i>Cinara pini</i> (Linnaeus, 1758), <i>Schizolachnus pineti</i> (Fabricius, 1781)	<i>Camponotus fallax</i> , <i>C. vagus</i> , <i>Dolichoderus quadripunctatus</i> , <i>Formica cinerea</i> , <i>F. polystena</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> , <i>L. platythorax</i> , <i>Leptothorax</i> sp., <i>Myrmica</i> sp.
<i>Ulmus laevis</i> (except for halophores, inaccessible to ants)	<i>Tinocallis platani</i> (Kaltenbach, 1843)	<i>Formica cinerea</i> , <i>Lasius brunneus</i> , <i>L. emarginatus</i> , <i>L. fuliginosus</i> , <i>L. niger</i> ,

Table 3. The effect of illumination on the attendance of phanerophytes by ants in different habitats

Species of plants	Habitats									X
	G1.A16	X11	G5.1	G1.A5	G4.F	E2.1	G5.2	G1.11	G1.C2	
<i>Quercus robur</i>	1.43± 0.05	2.78± 0.07	1.79±0.01	2.35± 0				1.35 ± 0.09		1.94 ± 0.27
<i>Acer platanoides</i>	1.0 ± 0.02	1.85± 0.07	1.49± 0.35							1.45 ± 0.24
<i>Acer platanoides</i> <i>undergrowth</i>	0.8 ± 0.02									0.83 ± 0.02
<i>Fraxinus excelsior</i>	1.8 ± 0.15	2.24± 0.26	4.53± 0.34							2.86 ± 0.84
<i>Carpinus betulus</i>	1.24 ± 0.07									1.24 ± 0.07
<i>Euonymus verrucosus</i>	1.02 ± 0									1.02 ± 0
<i>Ulmus glabra</i>	1.02 ± 0							0.51 ± 0.01		0.76 ± 0.25
<i>Ulmus laevis</i>			1.31± 0.18							1.31 ± 0.18
<i>Sambucus nigra</i>	0.18 ± 0	1.87± 0		2.35± 0						1.46 ± 0.65
<i>Robinia pseudoacacia</i>		3.06± 0.10	5.85± 0.26		4.98± 0.23	10.8±0 (\$)	13.18±0.26			7.57 ± 1.89
<i>Populus alba</i>		1.82± 0.12	1.45± 0.12			10.8 ± 0 (\$)		3.46 ± 0.28 (trees) 20.0 ± 0 (\$)		7.50 ± 3.55
<i>Tilia cordata</i>		1.21± 0.04	4.01± 0.18	2.35 ± 0						2.52 ± 0.81
<i>Betula pendula</i>		5.16± 0.33	4.88± 0.42		2.25 ± 0					4.09 ± 0.92
<i>Populus nigra</i>		4.36± 0.36	2.22± 0.28			10.8 ± 0 (\$)		7.47 ± 0.50		6.21 ± 1.87
<i>Juglans mandshurica</i>		3.10± 0.19	4.93± 0.35							4.01 ± 0.91
<i>Aesculus hippocastanum</i>		1.45± 0.09	2.05± 0.41							1.75 ± 0.30
<i>Acer saccharinum</i>		2.34± 0.38	2.59± 0.23							2.46 ± 0.12
<i>Quercus rubra</i>		3.10± 0.16	1.98± 0.08						3.0±0 (trees) 3.0 ± 0 (\$)	2.77 ± 0.26
<i>Pinus sylvestris</i>		4.77			5.15± 0.17					4.96 ± 0.19
<i>Amorpha fruticosa</i>		5.35± 0			2.26 ± 0			6.80 ± 0.19		4.80 ± 1.34
<i>Padus serotina</i>		0.55± 0			3.57± 0.11					2.06 ± 1.51
<i>Padus avium</i>					4.68± 0.20					4.68 ± 0.20
<i>Salix fragilis</i>			1.26± 0.12					6.47 ± 0.43 15.7 ± 0 (\$)		7.81 ± 4.22

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<i>Acer negundo</i>			2.02± 0.08					0.63 ± 0.01		1.32 ± 0.69
<i>Acer negundo</i> saplings			36.6± 2.39			6.65±0				21.62± 14.97
<i>Pyrus communis</i>			4.62 ± 0							4.62 ± 0
<i>Populus tremula</i>			2.00 ± 0					1.78 ± 0.11		1.89 ± 0.11
<i>Salix alba</i>			1.98± 0.17							1.98 ± 0.17
<i>Acer campestre</i>									3.0 ± 0	3.0 ± 0
X	1.06± 0.16	2.93± 0.43	4.60± 1.80	2.35± 0	3.81± 0.54	9.76± 1.03	13.18±0.26	6.41 ± 2.09	3.0 ± 0	

(Note: \$- saplings)

Additions to monograph of Cerretti *et al.*, 2020: The world woodlouse flies (Diptera, Rhinophoridae)

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Abstract

Recently presented faunistics' data omitted in the monograph (Cerretti *et al.*, 2020) are given for 23 woodlouse flies' (Diptera: Rhinophoridae) species according to 28 literary sources, including 15 those are not indicated in the monograph.

Keywords: *Rhinophoridae, word catalog, additions, corrections.*

Received: 9 May 2020; Revised: 26 December 2020; Online: 31 December 2020

Introduction

Rhinophoridae (Diptera: Calyptrata) comprises of 33 genera and 177 species worldwide (Cerretti *et al.*, 2020). The larvae are obligate endoparasitoids of woodlice (terrestrial Isopoda, Malacostraca, Crustacea). The eggs deposited on the soil hatch and the 1st instar larva attaches itself to the body of a passing woodlouse. The larva may waves its anterior end slowly forward and sideward in an attempt to attach itself to the body of a passing woodlouse (Bedding, 1973; Bürgis, 1991a, b, 1992a, b; Pape and Arnaud, 2001; Wood *et al.*, 2018). Adults often visit flowers; some species may be trapped in great numbers by yellow dishes, found on foliage or sitting on tree trunks and may be captured by Malaise traps, on vertebrate carcasses or they emerge from heaps of decaying wood (Petanidou, 1991; Verves *et al.*, 2019).

Materials and Methods

The complex revisions of high ranges' systematic groups (families, etc.) determine the direction of the study of these taxa for many decades to come. Therefore, all data in such publications should be as complete as possible. Unfortunately, a comparison of the materials of the species catalog (Cerretti *et al.*, 2020) with previously published data showed a number of drawbacks. This is an incomplete reflection of the data of the cited works and the lack of information on a number of important faunistics' publications (Villeneuve,

1929; Sassaman and Garthwaite, 1984; Hedström, 1988; Petanidou, 1991; Zeegers and Veen, 1993; Pape *et al.*, 1995; González, 1998; Menzel and Ziegler, 2002; Dumčius and Pakalniškis, 2004; Verves, 2004; Sharkey, 2005; Pakalniškis *et al.*, 2006; Zeegers, 2009; Pohjoismäki and Kahanpää, 2014; Koçak and Kemal, 2015) in the list of references. Below are the necessary additions that are not in the catalog for the use of the faunal data of the peer-reviewed work.

Results

1. *Baniassa fenestrata* Zeegers, 2008. Afrotropical: Yemen (Zeegers, 2008).
2. *Bezzimyia bulbosa* Pape and Arnaud, 2001. Nearctic: USA: Florida, Texas (Peris and González-Mora, 2007). Neotropical: Panama (Peris and González-Mora, 2007).
3. *Bezzimyia busckii* Townsend, 1919. Neotropical: Colombia (Sharkey, 2005).
4. *Bezzimyia thompsonorum* Pape and Arnaud, 2001. Nearctic: USA: Texas (Pape and Arnaud, 2001).
5. *Melanophora roralis* (Linnaeus, 1758). Nearctic: USA: North Carolina (Sassaman and Garthwaite, 1984). Neotropical: Chile: Chacabuco, Elqui, Llanquihue (González, 1998); Virgin Is.: St. Thomas I. (Crosskey, 1977). Palearctic: Finland (Pohjoismäki and

- Kahanpää, 2014); Lithuania (Dumčius and Pakalniškis, 2004; Pakalniškis *et al.*, 2006); Madeira (Peris and González-Mora, 2007); Serbia (Fauna europaea) instead of former “Yugoslavia” in Cerretti *et al.*, 2020.
6. *Oplisa aterrima* Strobl, 1899. Palaearctic: Malta (Ebejer, 2011).
 7. *Oplisa oldenbergi* (Herting, 1961). Palaearctic: Bulgaria (Zeegers, 2011); The Netherlands (Zeegers and Veen, 1993).
 8. *Oplisa pollinosa* Kugler, 1978. Palaearctic: Palestinian Authority (Koçak and Kemal, 2015); Syria: Golan Heights (Kugler, 1978).
 9. *Oplisa tergestina* (Schiner, 1862). Palaearctic: The Netherlands (Zeegers and Veen, 1993); Ukraine: Donetzk (Verves, 2005).
 10. *Paykullia brevicornis* (Zetterstedt, 1844). Palaearctic: Finland (Pohjoismäki and Kahanpää, 2014).
 11. *Paykullia kugleri* (Herting, 1961). Palaearctic: Palestinian Authority (Kugler, 1978); Syria: Holan heights (Kugler, 1978).
 12. *Paykullia maculata* (Fallén, 1815). Palaearctic: Finland (Pohjoismäki and Kahanpää, 2014); Lithuania (Dumčius and Pakalniškis, 2004; Pakalniškis *et al.*, 2006); Russia: Moscow (Internet-2013), Ukraine: Kyiv (Verves, 2004).
 13. *Paykullia nubilipennis* (Löw, 1847). Palaearctic: France: mainland (Herting, 1961).
 14. *Phyto abbreviata* Villeneuve, 1920. Palaearctic: Egypt: Mariout (Villeneuve, 1929).
 15. *Phyto adolescens* Rondani, 1861. Palaearctic: Greece (Petanidou, 1991). Comments: Cerrretti *et al.*, 2020: 87, treated this species as “firstly recorded” for Greece.
 16. *Phyto cingulata* (Zetterstedt, 1844): Palaearctic: Germany (Dunk, 1999).
 17. *Phyto discrepans* Pandellé, 1896: Palaearctic: Germany (Herting, 1961); The Netherlands (Zeegers and Veen, 1993); Ukraine: Cherekasy (Verves, 2005), Crimea (Verves, 2005), Luhansk (Verves, 2005). Australasian: introduced to New Zealand (Peris and González-Mora, 2007).
 18. *Phyto fernandezyepezi* Baez, 1988: Palaearctic: Canary Is.: Tenerife (Peris and González-Mora, 2007).
 19. *Phyto melanocephala* (Meigen, 1824): Palaearctic: Sweden (Hedström, 1988); Russia: “Central European Territory”; misidentification; correctly: South European Territory: Krasnodar (Verves, 2005).
 20. *Phyto similis* Stein 1924: Palaearctic: The Netherlands (Zeegers and Veen, 1993).
 21. *Rhinomorinia sarcophagina* (Schiner, 1862): Palaearctic: Lithuania (Dumčius and Pakalniškis, 2004; Pakalniškis *et al.*, 2006).
 22. *Rhinomorinia verticalis* Crosskey, 1977: Afrotropical: South Africa: KwaZulu-Natal (Peris and González-Mora, 2007).
 23. *Rhinophora lepida* Meigen, 1824 Palaearctic: Austria (Menzel and Ziegler, 2002); Italy [incorrectly as ‘firstly recorded’]: mainland (Pape *et al.*, 1995); Israel (Kugler, 1978); Ukraine: Poltava (Verves and Khrokalo, 2010), Sumy (Verves and Khrokalo, 2010).

Acknowledgements

The research leading to this publication has received funding from “The support of the priority research areas development of Ukraine, KPKVK 6541230”

References

- Bedding, R.A. 1973. The immature stages of Rhinophorinae (Diptera: Calliphoridae) that parasitise British woodlice. Transactions of the Royal Entomological Society of London 125(1): 27–44.
- Bürgis, H. 1991a. Parasitische Hautflügler aus Puparien der in Asseln schmarotaenden Aselfliegen. Teil 1: Eine neue Wespe. Mikrokosmos 80: 295–299.
- Bürgis, H. 1991b. Parasitische Hautflügler aus Puparien der in Asseln schmarotaenden Aselfliegen. Teil 2: Ein inhaltsreicher Fund. Mikrokosmos 80: 368–371.
- Bürgis, H. 1992a. Parasitische Hautflügler aus Puparien der in Asseln schmarotaenden Aselfliegen. Teil 3: Detektivische Ermittlungen. Mikrokosmos 81(2): 50–52.
- Bürgis, H. 1992b. Parasitische Hautflügler aus Puparien der in Asseln schmarotaenden

- Aselfliegen. Teil 4: Die Asselfliege, Schlussbemerkungen. Mikrokosmos 81: 100–104.
- Cerretti, P., Davide, D., Gisondi, S., Lo Giudice, G. and Pape, T. 2020. The world woodlouse flies (Diptera, Rhinophoridae). ZooKeys 903: 1–130.
- Crosskey, R.W. 1977. A review of the Rhinophoridae (Diptera), and a revision of the Afrotropical species. Bulletin of British Museum (Natural History). Series B. Entomology 36(1): 1–66.
- Dumčius, O. and Pakalniškis, S. 2004. New for Lithuania Diptera species found in 1993–2004. In: V. Jonaitis (ed.), New and rare for Lithuania insect species. Records and descriptions. Vilnius: Lithuanian Entomological Society. Vol. 16, pp. 53–61.
- Dunk, K. von der 1999. Zweiflügler aus Bayern. XIX (Diptera: Rhinophoridae, Hippoboscidae, Destridae, Hypodermatidae, Gasterophilidae). Entomofauna 20(29): 445–448.
- Ebejer, M.J. 2011. A note on some Rhinophoridae from the Mediterranean Region. Bulletin of the Entomological Society of Malta 4: 73–77.
- Fallén C.F. 1815. Beskrifning öfver några rot-fluge arter, hörande till slägterna. Thereva och Ocyptera. Kongliga Vetenskaps Academiens Handlingar, Ser. 3, 3: 229–240.
- González, C.R. 1998. First record for Chile of *Melanophora roralis* (Linnaeus) (Diptera: Rhinophoridae). Acta entomologica chilena 22: 111–112.
- Hedström, L. 1988. Swedish insect records – report 4. Entomologisk Tidskrift 109: 139–149.
- Herting, B. 1961. 64e. Rhinophoridae. In: E. Lindner (ed.), Die Fliegen der paläarktischen Region 9(216): 1–36. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.
- Koçak, A.Ö. and Kemal, M. 2015. Initial results of the entomofauna of SW Asia, based upon the info-system of the Cesa (excl. Lepidoptera). Priamus 35: 1–1186.
- Kugler, J. 1978. The Rhinophorinae (Diptera) of Israel. Israel Journal of Entomology 12: 65–106.
- Menzel, F. and Ziegler, J. 2002. Neue Funde von Zweiflüglern (Diptera) aus dem Nationalpark Hohe Tauern in Österreich nebst Angaben zum Blütenbesuch und der Beschreibung von zwei neuen Trauermücken-Arten (Sciaridae). Studia dipterologica 8: 355–409.
- Pakalniškis, S., Bernotiene, R., Lutovinovas, E., Petrarca, V., Podėnas, S., Rimšaite, J., Saether, O.A. and Spungis, V. 2006. Checklist of Lithuanian Diptera. New and rare for Lithuania insect species, records and descriptions 18: 1–159. Lithuanian Entomological Society, Vilnius.
- Pape, T. and Arnaud, P., Jr. 2001. *Bezzimyia* – a genus of New World Rhinophoridae (Insecta, Diptera). Zoologica Scripta 30: 257–297. <https://doi.org/10.1046/j.1463-6409.2001.00064.x>
- Pape, T., Richter, V., Rivosecchi, L. and Rognes, K. 1995. Diptera Hippoboscoidea, Oestroidea. In: A. Minelli, S. Ruffo and S. La Posta, (eds.), Checklist delle specie della fauna italiana. Fascicolo 78: 1–36. Calderini, Bologna.
- Peris, S.V. and González-Mora, D. 2007. Claves de identificación para los géneros de Calliphoridae del mundo. Subfamilias con vena remigium desnuda: Subfamilia Rhinophorinae (Diptera, Calliphoridae). Boletín de la Real Sociedad Española de Historia Natural (Sección Biologica) 102 (1–4): 35–60. <https://pdfs.semanticscholar.org/49b8/10b86ac37a511a21ae70aff4>
- Petanidou, T. 1991. Pollinating fauna of a phrygic ecosystem: species list, pp. 1–11. Verslagen en technische Gevegens; Instituut voor Taxonomische Zoölogie (Zoölogisch Museum) Universiteit van Amsterdam.
- Pohjoismäki, J.L.O. and Kahanpää, J. 2014. Checklist of the superfamilies Oestroidea and Hippoboscoidea of Finland (Insecta, Diptera), pp. 383–408. In: J. Kahanpää and J. Salmela, (eds.), Checklist of the Diptera of Finland. ZooKeys 441: 1–408. doi: 10.3897/zookeys.441.7252
- Sassaman, C. and Garthwaite, R. 1984. The interaction between the terrestrial isopod *Porcellio scaber* Latreille and one of its dipteran parasites, *Melanophora roralis* (L.) (Rhinophoridae). Journal of Crustacean Biology 4(4): 595–603.
- Sharkey, M.J. 2005. Colombian Species Database, <http://www.uky.edu/~mjshar0/colombia/en-database.html>.

- Verves, Y.G. 2004. A checklist of Ukrainian Rhinophoridae (Diptera). *Studia dipterologica* 11(2): 609–613.
- Verves, Y.G. 2005. Faunistic and taxonomical notes of Rhinophoridae (Diptera) with special reference of Ukrainian fauna. *Entomological Problems* 35(1): 69–74.
- Verves, Y.G. and Khrokalo, L.A. 2010. The new data on Calliphoridae and Rhinophoridae (Diptera) from Ukraine. *Ukrainska Entomofaunistyka* 1(1): 23–54.
- Verves, Y., Zeegers, T., Barták, M. and Kanavalová, L. 2019: The family Rhinophoridae (Diptera) in the Czech Republic and new records from Jordan and Bulgaria. *In*: Š. Kubík, and M. Barták, (eds.), 11th Workshop on biodiversity, Jevany, Česká zemědělská univerzita v Praze. Fakulta Agrobiologie, Potravinových a Přírodních Zdrojů, pp. 163–174.
- Villeneuve, J. 1929. Descriptions de diptères égyptiens. *Bulletin de la Société entomologique de Égypte* (N. S.) [1928] 12: 43–46.
- Wood, C.T., Nihei, S.S. and Araujo, P.B. 2018. Woodlice and their parasitoid flies: revision of *Isopoda* (Crustacea, Oniscidea) – *Rhinophoridae* (Insecta, Diptera) interaction and first record of a parasitized Neotropical woodlouse species, pp. 401–414. *In*: E. Hornung, S. Taiti and K. Szlavecz (eds.). *Isopods in a Changing World*. ZooKeys 801: 1–518.
- Zeegers, Th. 2008. Order Diptera, family Rhinophoridae, pp. 732–740. *In*: Harten, A. van (ed.), *Arthropod fauna of the United Arab Emirates 1*: 1–754. Dar Al Ummah, Abu Dhabi.
- Zeegers, Th. 2009. Tachinidae, Calliphoridae and Oestridae (Diptera) collected in Siberia by Dutch expedition. *Euroasian Entomological Journal* 8(4): 431–436.
- Zeegers, Th. 2011. New and little known Rhinophoridae (Diptera) from Turkey. *Stuttgarter Beiträge zur Naturkunde A, Neue Serie* 4: 313–320.
- Zeegers, Th. and Veen, M. van 1993. Pissebedvliegen (Rhinophoridae) in Nederland: een voorlopig overzicht. *De Vliegenmepper* 2(2): 1–10.

***Deuterophlebia* Edwards, 1922 (Diptera: Deuterophlebiidae) an Enigmatic Primitive Diptera (Insecta) from Kashmir Himalaya**

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Abstract

Mountain midges (Deuterophlebiidae) are cold water hill stream insects restricted to Nearctic and Palearctic regions. Deuterophlebiidae is believed to be a primitive lineage of Diptera and so elicits a considerable degree of interest in aquatic entomologists. Due to their restricted geographic distribution and specialized habitats, very little information is available on these primitive enigmatic insects from India. Here we report the discovery of a larva of mountain midge from Kashmir Himalaya after a time gap of forty nine years.

Keywords: *Deuterophlebia*, *Diptera*, *Mountain midges*, *Hill stream*, *Kashmir Himalaya*.

Received: 5 January 2020; Revised: 4 December 2020; Online: 31 December 2020

Introduction

Diptera is one among the world's four most diverse group of insects eminently acclimatized for life at higher elevations. The group is one of the most commonly recognized and widespread insects all over the world (Sarwar, 2020). Out of 158 families of Diptera 41 have aquatic representatives with about 46,000 aquatic species representing about 30% of all formally described species of Diptera (Alder and Courtney, 2019). Every single dipteran fly has its own biological distinctiveness and ecological importance and some aquatic Diptera are regarded as "ecosystem engineers" as these species can considerably change the abiotic habitat and thus affect the ecology of other organisms and associated ecosystem processes (Wotton *et al.*, 1998; Alder and Courtney, 2019). One such case is presented by a cryptic monotypic family of Mountain Midges (Diptera: Deuterophlebiidae: *Deuterophlebia*) that are highly specialized hill stream insects. Mountain midges are mysterious nematocer-

ous flies currently represented by a single genus with 15 species restricted to Nearctic and Palearctic regions (Wiegmann and Yeates, 2017; Pape and Thompson, 2019). *Deuterophlebia* is evoking considerable interest in both dipterists and aquatic entomologists, not only for their morphological and ecological distinctiveness, but also for its primeval lineage (McAlpine, 1981).

The immature stages are highly specialized to inhabit cold fast flowing torrential streams. The larvae have distinct eversible crochet-tipped prolegs and streamlined pupae. The prolegs have elongate setae both anteriorly as well as posteriorly. The mouth parts of adults are atrophied (Courtney, 1994). All larvae are grazers, noshing on the delicate film of periphyton on submerged rocks in streams. Head capsule is eucephalous. Antenna is elongated and split widely. Abdomen eight segmented with segments I-VII with paired, crochet-tipped,

lateral prolegs (Edwards, 1922). Segments IV and V are broadest. Thorax is dorsoventrally flattened, with three discrete divisions separated by lateral incisions. Adult longevity is brief, under two hours in males and not more than 24 hours in females. Aerial mating is presumed, as no case of mating is observed. Fecundity is low (Courtney, 1991).

The Family Deuterophlebiidae and genus *Deuterophlebia* was erected by F.W. Edwards (1922) based on specimens collected by F.J. Mitchell from Srinagar, Kashmir, India. The Palearctic species of *Deuterophlebia* is represented by eight species viz., *D. mirabilis* Edwards, 1922; *D. nipponica* Kitakami, 1938; *D. tyosenensis* Kitakami, 1938; *D. sajanica* Jedlicka & Halgos, 1981; *D. bicarinata* Courtney, 1994; *D. blepharis* Courtney, 1994; *D. brachyrhina* Courtney, 1994; *D. oporina* Courtney, 1994 (Courtney, 1994; Pape and Thompson, 2019). Among these, *D. mirabilis* (Kashmir, Sikkim); *D. blepharis* (Sikkim); *D. brachyrhina* (Arunachal Pradesh); *D. oporina* (Arunachal Pradesh) and an undescribed species of *Deuterophlebia* sp. (Courtney, 1994) have been reported from the Indian Himalaya. Overlooking the revision of Palearctic *Deuterophlebia* by Courtney (1994), Banerjee *et al.* (2018) reported only one species *D. mirabilis* from the Indian Himalaya. Courtney's (1994) revision and descriptions of new species from Himalaya were based on adult materials collected and deposited by Schmid in National Museum of Natural History, Washington, USA and Biosystematics Research Centre, Ottawa Canada. Larvae of 'an apparently undescribed species' were found in melt water streams of the northern Pir Panjal Range and the south slope of the Himalaya (Courtney, 1994), and additional observations were recorded by Dubey and Kaul (1971). All the species descriptions of *Deuterophlebia* from Indian Himalaya were based on adults and definite larvae-pupa-adult relationship were never established including for the widespread species *D. mirabilis* hence, definite species level identification of immature stages are difficult at present. Since 1971, there was no report of this rare family of Diptera from Indian Himalaya. During a recent field study in Kashmir, a single larva of *Deuterophlebia* was collected and reported

here after forty nine years.

Materials and Methods

The larva was collected by using D-net (30 cm wide base and 30 cm long) with 0.5 mm mesh size (Ligeiro *et al.*, 2020). The sampling net was placed on stream bed at downstream end of the reach, so that the natural flow that directs organisms into the net (Sabha *et al.*, 2020). The bottom substrate was disturbed for at least 1 minute by kicking method to dislodge the upper layer of cobbles or gravel and to scrape the underlying bed (Ilmonen and Paasivirta, 2005).

One larva mounted with Hoyer's medium on slide and was photographed (Figure 2) using Leica M205A stereo zoom microscope.

Material examined: One larva mounted with Hoyer's medium on slide. Locality: Thajwas stream, Thajwas, Kashmir, India. Longitude: 75° 16' 10.5" N; Latitude: 34° 17' 25.6" E; Altitude: 2798 m. Date: 12 October 2018. The specimen is deposited at Zoological Survey of India, Southern Regional Centre, Chennai, India.

Results and Discussion

Single larva of *Deuterophlebia* was found in a riffle of Thajwas stream originating from famous Thajwas Glacier. The glacier lies on the great flank of Kashmir Himalayas surrounded by picturesque plateaus and snow field. The temperature of the melt water was 4°C when the larva was discovered. The larva occurred in a riffle with rocky substrata covered with thick layer of periphyton. The average depth of the stream cross-section was about 9.5 inches and current velocity of the stream was 3 m/s the day larva was found.

The collected specimen was chocolate brown in colour which turned into white in alcohol. The larva is not identified up to species level due to non-availability of larval descriptions. The length of larva was 6mm; prolegs tipped with 13 rows of crochet rows, indicating the 4th instar stage (Fig. 2). Earlier collection of the larvae of *Deuterophlebia* from the Western Himalaya was from the headwaters of Alhni River (Himachal Pradesh) below snow fields and glaciers at 4000m (Dubey and Kaul, 1971).



Figure 1: Thajwas stream, collection locality of the larva.

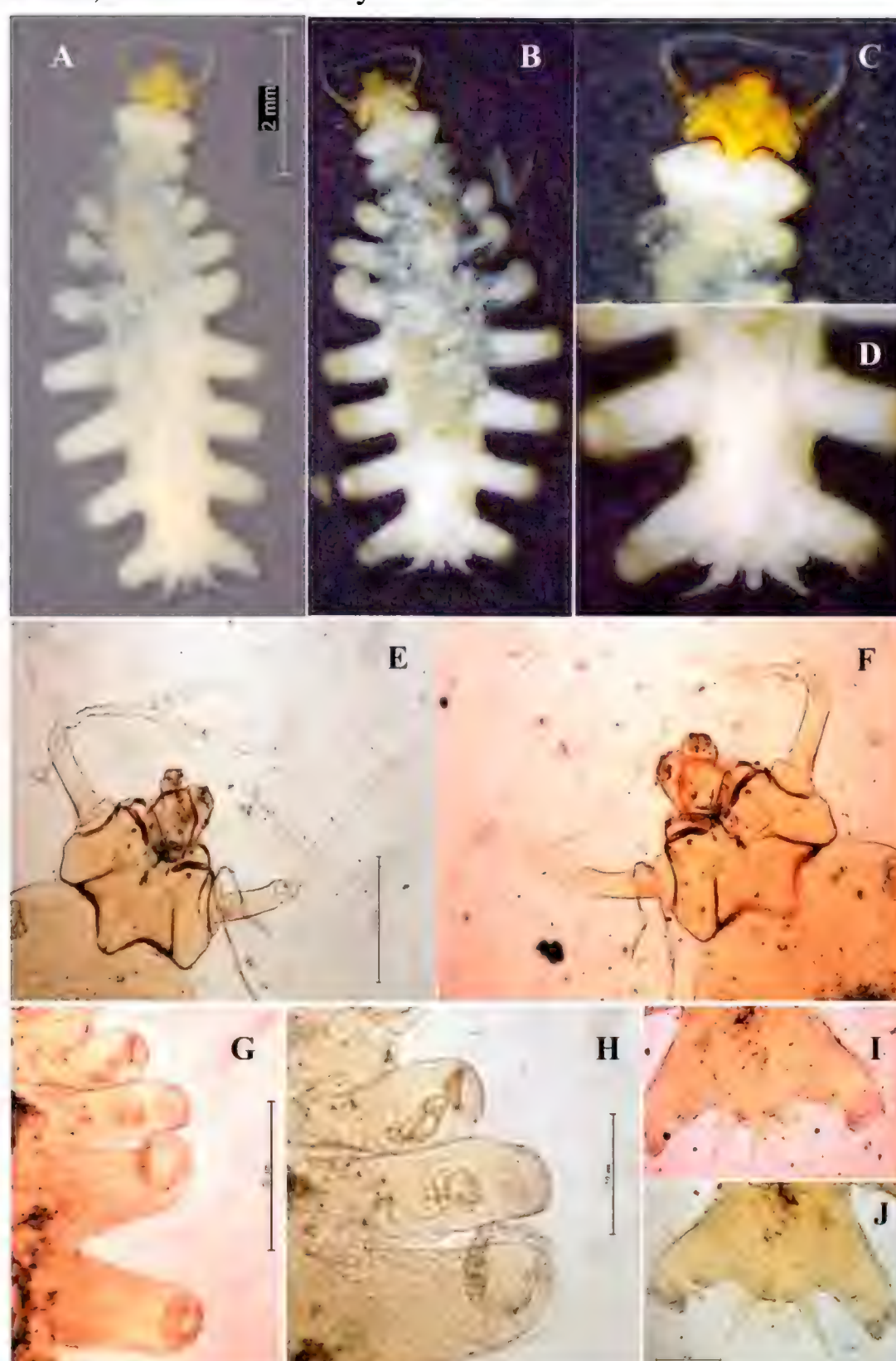


Figure 2 (A-J): *Deuterophlebia*, instar IV, ventral view of head, thorax, and abdominal segments.

They observed gregarious association of *Deuterophlebia* to algae-covered stones along with Chironomidae, Simuliidae and Blepharoceridae.

Rediscovery of *Deuterophlebia* sp. indicate the pristine nature of the streams in the basin. Extensive survey of Himalaya and collection of more larvae and adults coupled

with DNA analysis will reveal the correct species identity, diversity, ecology and distribution of *Deuterophlebia* in Kashmir Himalaya.

Acknowledgments

The research work was conducted as part of Research project “Anthropogenic impacts and their management options in different ecosystems of the Indian Himalayan Region” sponsored by National Mission on Himalayan Studies (NMHS) under the aegis of Ministry of Environment, Forest & Climate Change, Govt. of India and the financial assistance received from NMHS under the project to accomplish this research is thankfully acknowledged. KAS and other authors of this manuscript thank Director, Zoological Survey of India for providing facilities to conduct the study.

References

- Adler, P.H. and Courtney, G.W. 2019. Ecological and societal services of aquatic diptera. *Insects* 10(3): 70.
- Banerjee, D., Naskar, A., Sengupta, J., Hazra, S. and Maity, A. 2018. Insecta: Diptera. *In: K. Chandra, D. Gupta, K.C. Gopi, B. Tripathy, and V. Kumar (eds.) Faunal Diversity of Indian Himalaya: 1-872.* Kolkata: Director, Zoological Survey of India.
- Courtney, G.W. 1991. Life history patterns of Nearctic mountain midges (Diptera: *Deuterophlebiidae*). *Journal of the North American Benthological Society* 10: 177–197.
- Courtney, G.W. 1994. Revision of Palaearctic mountain midges (Diptera: *Deuterophlebiidae*), with phylogenetic and biogeographic analyses of world species. *Systematic Entomology* 19: 1-24.
- Dubey, O.P. and Kaul, B.K. 1971. Torrenticole insects of the Himalaya. IV. Some observations on the ecology and the characters - insect communities of the R. Alhni. *Oriental Insects* 5: 47-71.
- Edwards, F.W. 1922. *Deuterophlebia mirabilis*, gen. et sp.n., a remarkable dipterous insect from Kashmir. *Annals and Magazine of Natural History* 9: 379-387.
- Ilmonen, J. and Paasivirta, L. 2005. Benthic macrocrustacean and insect assemblages in relation to spring habitat characteristics: patterns in abundance and diversity. *Hydrobiologia* 533: 99-113.
- Ligeiro, R., Hughes, R.M., Kaufmann, P.R., Heino, J., Melo, A.S. and Callisto, M. 2020. Choice of field and laboratory methods affects the detection of anthropogenic disturbances using stream macroinvertebrate assemblages. *Ecological Indicators* 115: 106382.
- McAlpine, J.F. 1981. Morphology and terminology-Adults. *In: J.F. McAlpine, B.V. Peterson, G.E. Shewell, H.J. Teskey, J.R. Vockeroth and D.M. Wood, (coordinators). Manual of Nearctic Diptera, Volume 1. Research Branch, Agriculture Canada Monograph 27: 9-63.*
- Pape, T. and Thompson, F.C. (eds.). 2019. *Systema Dipterorum* (version 2.0, Jan 2011). *In: Species 2000 & ITIS Catalogue of Life, 2019 Annual Checklist* (Roskov Y., Ower, G., Orrell, T., Nicolson, D., Bailly, N., Kirk, P.M., Bourgoin, T., DeWalt, R.E., Decock, W., Nieukerken, E. van, Zarucchi, J., Penev, L., eds.). Digital resource at www.catalogueoflife.org/annual-checklist/2019. Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-884X.
- Sabha, I., Khanday, S.A., Islam, S.T. and Bhat, S.U. 2020. Longitudinal and temporal assemblage patterns of benthic macroinvertebrates in snow melt stream waters of the Jhelum River Basin of Kashmir Himalaya (India). *Ecohydrology* 13(7), e2236.
- Sarwar, M. 2020. Typical Flies: Natural History, Lifestyle and Diversity of Diptera. *In: Life Cycle and Development of Diptera.* IntechOpen. DOI: 10.5772/intechopen.91391.
- Wiegmann, B.M. and Yeates, D.K. 2017. Phylogeny of Diptera. *In: A.H. Kirk-Spriggs, & B.J. Sinclair (eds.) Manual of Afrotropical Diptera. Volume 1. Introductory chapters and keys to Diptera families. Suricata 4. Pretoria: South African National Biodiversity Institute pp. 253–265.*
- Wotton, R.S., Malmqvist, B., Muotka, T. and Larsson, K. 1998. Fecal pellets from a dense aggregation of suspension-feeders in a stream: An example of ecosystem engineering. *Limnology and Oceanography* 43: 719–725.

First record of *Monaeses israeliensis* Levy, 1973 (Araneae: Thomisidae) from India

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Abstract

The thomisid spider *Monaeses israeliensis* Levy, 1973 is recorded for the first time from India. Female of the newly recorded spider species is described and illustrated.

Keywords: *Thomisidae, Monaeses israeliensis, India, New record.*

Received: 21 December 2019; Revised: 28 December 2020; Online: 31 December 2020

Introduction

The little-known crab spider genus *Monaeses* Thorell, 1869 is an old world genus and consists of 27 species of which only 4 species were reported so far from India (Sebastian and Peter 2009; WSC, 2020). Tikader (1963) described the first *Monaeses* species from India, subsequently three other species were described by Tikader (1980) and Gajbe and Rane (1992).

During the faunastic survey conducted to Southern Western Ghats of Wayanad districts, Kerala, we could collect the specimen of *Monaeses israeliensis* Levy, 1973. Search of literature revealed that the species has not been reported earlier from India (Levy, 1973; Bayram *et al.*, 2007; Sebastian and Peter, 2009; Kiany *et al.*, 2017; Yuan *et al.*, 2019; WSC, 2020) and hence the present finding forms a new record. Distribution of the genus was found to be confined to Western, Central & Northern India (Tikader, 1963; Tikader, 1980; Gajbe and Rane, 1992). Here we report the range extension of the genus to Southern India. A detailed description and illustrations of the newly recorded species *Monaeses israeliensis* Levy, representative of a lesser known genus *Monaeses* Thorell has been provided here in the light of present context of world spider taxonomy.

Materials and Methods

The present specimen was collected by bush beating and was examined under Leica M205A stereo zoom binocular micro-

scope and images captured with the camera model Leica DFC 500 and processed using extended focus montage LAS software (version 3.8.0). The measurements indicated in the text are in millimeters. Leg measurements are given as: Total length (femur, patella + tibia, metatarsus, tarsus). The terminology used in the text mainly follows Ono (1988) and Tang and Li (2010).

Abbreviations used: CL= Cephalothorax length, CW= Cephalothorax width, AL= Abdominal length, AW= Abdominal width, TL= Total length, AME= Anterior median eyes, ALE= Anterior lateral eyes, PME= Posterior median eyes, PLE= Posterior lateral eyes; WSC= World Spider Catalog.

The specimen is deposited in the National Zoological Collections of Zoological Survey of India, Western Ghat Regional Centre, Kozhikode.

Taxonomy

Monaeses Thorell, 1869

Type species: *Monaeses paradoxus* (Lucas, 1846)

Diagnosis: For diagnostic features and description, see Ono (1988).

Monaeses israeliensis Levy, 1973

Monaeses israeliensis Levy, 1973, Israel Journal of Zoology 22: 107-141.

Monaeses israeliensis Levy, 1985, Israel Academy of Sciences and Humanities, Jerusalem: 115pp.

Monaeses israeliensis Bayram *et al.*, 2007, Munis Entomology and Zoology 2: 129-136.

Monaeses israeliensis Kiany *et al.*, 2017, Arachnologische Mitteilungen 53: 1-8.

Monaeses israeliensis Yuan *et al.*, 2019, Acta Arachnologica Sinica 28(2): 106-108.

Description:

Female: CL- 1.81, CW- 1.52, AL- 5.84, AW- 1.32, TL- 7.65.

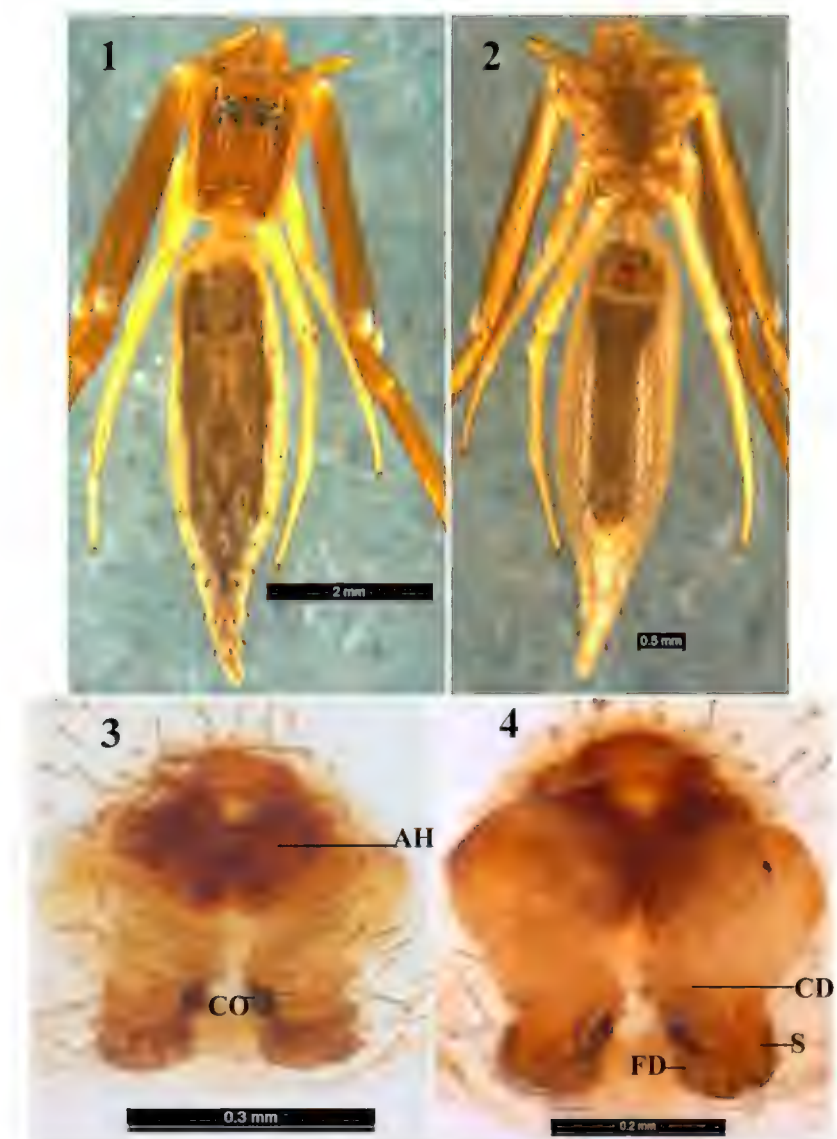
Cephalothorax (fig. 1) brownish grey, longer than wide, lateral margins almost parallel and narrowing in front, cephalic region elevated with cervical furrows, clothed with short stout setae. Eyes 8, black, ringed with white, arranged in two recurved rows, anterior row more recurved than posterior, eyes situated on the white tubercles, lateral tubercles larger than median, eye diameter: ALE>PLE>PME>AME, ocular quad trapezoid. Inter ocular distance: AME-AME=0.12, ALE-AME=0.21, ALE-ALE=0.52, PME-PME= 0.34, PLE-PME=0.32, PLE-PLE=0.63, ALE-PLE=0.34, AME-PME=0.26. Clypeus colour same as cephalothorax, wider than long, anterior margin concave, clothed with setae.

Chelicerae yellow, hairy, margins devoid of any tooth, dorsally clothed with setae, fangs yellow brown, small and broad. Maxillae and labium yellow, with scattered setae, apically scopulate, maxillae longer than wide and labium rhomboidal. Sternum brownish grey, oval, with setae (fig. 2).

Leg I & II brownish grey, leg II & IV yellowish white, metatarsi I & II with 5 pairs of short prolateral spines and metatarsi III & IV with 2 pairs of prolateral and 3 pairs of retrolateral short spines, tarsal claw 2, each with 5 teeth. Leg measurements: I 9.55 (2.69, 3.38, 2.35, 1.13); II 9.09 (2.89, 3.31, 2.01, 0.88); III 5.03 (1.04, 1.60, 1.9, 0.49); IV 6.61 (1.80, 1.94, 2.20, 0.67). Leg formula 1243.

Abdomen (figs. 1 and 2) grey with border yellowish white, slender, extending beyond the spinnerets and ends with a short tail, margin clothed with setae, each lateral side of the abdomen with 7 white longitudinal parallel lines extending from apical end to spinnerets; venter with a median grey band extending from epigastric furrow to base of spinneret, with conspicuous folds and bristles; anterior spinnerets grey, close, posterior spinnerets white, wide, hairy.

Epigynum-Internal genitalia (figs. 3 and 4): Epigynum with strongly sclerotised anterior hood, rhomboidal in appearance, copulatory opening distinct and semicircular; spermathecae twisted and convoluted, copulatory ducts wider and longer than spermatheca, fertilization ducts distinct.



Figures 1–4. *Monaeses israeliensis* Levy female: **1.** Dorsal view; **2.** Ventral view; **3.** Epigynum, ventral view; **4.** Internal genitalia, dorsal view (Abbreviations used: S: Spermatheca, CD: Copulatory Duct, FD: Fertilization Duct, CO: Copulatory Opening, AH: Anterior Hood).

Material examined: 1♀ (Reg. No. ZSI/WGRC/IR.INV.13466), **India:** Kerala, Wayanad district, Sultan Bathery (11°40'17"N & 76°22'07"E, 863m), 27/ix/2016, Coll. P.M. Sureshan.

Distribution: Greece, Turkey, Israel, Lebanon, Iran, Central Asia, China, **India (New record).**

Remarks: The internal genitalia of the recorded species has shown greater resemblance to the illustrations of Levi (1973).

Acknowledgements

The authors are grateful to Dr. Kailash

Chandra, Director, Zoological Survey of India for his encouragement, moral support and providing necessary facilities to carry out the work. The authors also thank Principal Chief Conservator of Forest, Kerala Forest and Wildlife Department for necessary support.

References

- Bayram, A., Danişman, T., Bolu, H. and Özgen, İ. 2007. Two records new for the Turkish araneofauna: *Tmarus piochardi* (Simon, 1866) and *Monaeses israeliensis* Levy, 1973 (Araneae: Thomisidae). *Munis Entomology and Zoology* 2: 129-136.
- Gajbe, U.A. and Rane, P.D. 1992. A new *Monaeses* spider from Madhya Pradesh, India (Araneae: Thomisidae). *Records of the Zoological Survey of India* 91: 395-397.
- Kiany, N., Sadeghi, S., Kiany, M., Zamani, A. and Ostovani, S. 2017. Additions to the crab spider fauna of Iran (Araneae: Thomisidae). *Arachnologische Mitteilungen* 53: 1-8.
- Levy, G. 1973. Crab-spiders of six genera from Israel (Araneae: Thomisidae). *Israel Journal of Zoology* 22: 107-141.
- Levy, G. 1985. Araneae: Thomisidae. In: *Fauna Palaestina, Arachnida II*. Israel Academy of Sciences and Humanities, Jerusalem. 115 pp.
- Ono, H. 1988. *A revisional study of the spider family Thomisidae (Arachnida, Araneae) of Japan*. Tokyo: National Science Museum. 252pp.
- Sebastian, P.A. and Peter, K.V. 2009. *Spiders of India*. Hyderabad: Universities Press (India) Pvt. Ltd. 614pp.
- Tang, G. and Li, S.Q. 2010. Crab spiders from Xishuangbanna, Yunnan Province, China (Araneae, Thomisidae). *Zootaxa* 2703: 1-105.
- Tikader, B.K. 1963. Studies on interesting south Indian crab-spiders (Family: Thomisidae). *Proceedings of the Indian Academy of Science* 58(B): 249-262.
- Tikader, B.K. 1980. Thomisidae (Crabspiders) : Fauna of India (Araneae). *Zoological Survey of India* 1: 1-239.
- World Spider Catalog. 2020. World Spider Catalog (version 21.5). Natural History Museum Bern. Online at: <http://wsc.nmbe.ch> (accessed on 23rd December 2020)
- Yuan, T., Niu, C.L., Ye, X.Y. and Zhang, Z.S. 2019. A newly recorded crab spider *Monaeses israeliensis* (Thomisidae) from Xinjiang, China. *Acta Arachnologica Sinica* 28(2): 106-108.

A study on antennal sensilla of the female worker castes of *Tetragonula iridipennis* (Smith) (Hymenoptera: Apidae)

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Abstract

Tetragonula iridipennis are a group of stingless bees which are effective pollinators of the tropics. They are believed to be endowed with efficient chemo (olfactory and gustatory) and visual sensory systems. Sensory perceptions in these insects are understood minimally, so the primary sensory organ – the antenna of the insects was probed to understand the sensilla diversity and distribution. Antennal sensilla profile of an insect often reflects the sensory repertoire of the insect. Light and scanning electron microscopic studies were carried to understand the antennal sensilla organization. Sensilla were typified by their morphological features. Sensilla basiconica, four subtypes of sensilla trichodea, sensilla trichodea curvata, sensilla placodea (pore plates) are the major types of antennal sensilla we could identify from *Tetragonula iridipennis*. The hygroreceptive sensilla ampullacea and CO₂ receptive sensilla ampullacea were conspicuously absent on the antenna of *Tetragonula iridipennis* suggesting differences in the sensory ecology of this bees.

Keywords: Stingless bees, antenna, chemosensory system, sensilla, pore plates.

Received: 18 February 2020; Revised: 29 December 2020; Online: 31 December 2020

Introduction

Diverse sensilla on the antenna of insects help them to perceive vital sensory signals from the surroundings they live, which is a crucial process for their survival and success. Sensilla provide the most important interface for insects with the surroundings as multimodal sensory stimuli like olfactory, mechanical and others like temperature, O₂ and humidity etc. are perceived through these sensory structures. In case of social insects like ants and honey bees volatile and non-volatile chemical signals are the language for communication between conspecifics which is perceived through different types of sensilla on the antenna (Li *et al.*, 2013). Foraging, mating and recognizing conspecifics are behaviors in social insects which are predominantly olfactory driven and sensed through antennal sensilla. Though antenna is considered as an olfactory organ endowed with numerous olfactory sensilla, mechano sensory and gustatory sensilla are also present in high numbers. Phylogenetic and life style based differences are reflected in the antennal sensilla types and their distribution of

each insect species. Further, in social insects the antennal sensilla shows variations in relation to caste, life stage, sex and behaviours (Herzner *et al.*, 2003; Li *et al.*, 2013; Carvalho *et al.*, 2017; Galvani *et al.*, 2017). For example in the ant *Oecophylla smaragdina* the major worker castes have a significantly larger number and more diverse profile of antennal sensilla than that of minor workers; sensilla basiconica and sensilla trichodea which are present in high numbers on the major worker antenna are associated with chemosensory perception, crucial for foraging and defense duties they are involved in (Babu *et al.*, 2011).

T. iridipennis (Stingless bees) are commonly known as dammer bees and are the smallest of the honey producing bees. Commonly found nesting in gaps of walls, logs, crevices and other concealed areas. They are mainly Neotropical, with certain species reported from tropical areas also (Makkar *et al.*, 1854; Rasmussen, 2013; Rahman *et al.*, 2015). Though they are important pollinators, knowledge about their sensory ecology and

organization of the chemo sensory systems are still not comprehensively understood. Although literature on the antennal sensilla of other honey bees (Slifer and Sekhon, 1961), *Mellipona spp.* (Ravaiano *et al.*, 2014; Carvalho *et al.*, 2017), Corbiculate bees (Fialho *et al.*, 2014) are extensive, but studies pertaining to the stingless bees of Indian terrain in particular *T. iridipennis* is missing. Therefore the present study aims to understand the sensilla types and distribution of sensilla on the antenna of *T. iridipennis* – the most common stingless bee of India. The study could help us to get insights into the peripheral sensory system of the insect in a comparative perspective. Understanding the antennal sensilla organization can give us fair comprehensions about the sensory perceptual capabilities of the insect, say for example whether it relies more on the light or depends on chemo sensory signals for social life based activities. Knowledge about the sensory structure and its organization is important as these insects are economically important and play a crucial role in the ecosystems as pollinators and as ecosystem service providers.

Materials and Methods

T. iridipennis was collected from nearby areas as they are easily available from nests they build on the exterior foundations and walls of houses. They were collected by aspirator and brought to the lab. They were etherized/cold anaesthetized before subjecting to experimental protocols. The antennae were carefully separated by using needle and forceps under a stereo microscope.

Scanning electron microscopy (SEM)

Scanning electron microscopy was carried out to study the detailed sensilla morphology of *T. iridipennis*. The procedure for the method is as follows:

1. Isolated antennae of *T. iridipennis* were immersed in 70% acetone.
2. The specimens were then dehydrated in different grades of acetone.
3. The antenna were then mounted on a brass stub and gold sputtered for 2 minutes (SPI-Module Gold Sputter Coater).

Observations were made using a JEOL JSM - 5800VL scanning electron microscope.

Results

Based on the shape and the other morphological features we could identify six types of sensilla from the antennae of *T. iridipennis*, majority of which appear to be chemosensory suggestive by their shape and structural features. The geniculate antenna of *T. iridipennis* has a flagellum which is approximately 76µm in length with 10 flagellomeres, scape and pedicel. Flagellomeres of the antenna are nearly equal in their length and breadth (Table 1). The characteristic club of flagellomeres seen on the antennae of many social insects is not conspicuous in *T. iridipennis*, however distal most flagellomere is the longest. Flagellomeres are endowed with different types of sensilla (sensory hairs) and sensilla placodea (pore plates) which are the units of the sensory interface for the insect. The distal flagellomeres bears diverse sensilla in comparison to the other flagellomeres. We noticed different types of mechano and chemo sensilla on the antenna. Placodea sensilla, a class of olfactory sensilla was found to be the most prominent type of sensilla on the antenna in terms of their greater number and distribution. A higher number of sensilla indicate a higher degree of sensory perception (Chapman, 1982).

Chemosensilla are predominantly present on the antenna of *T. iridipennis*. In addition, presence of many sub types of mechano sensilla suggests the reasonably well developed sensory repertoire of *T. iridipennis*. Sensilla placodea, sensilla basiconica, and subtypes of sensilla trichodea were observed in the present study (Table 2).

1. Sensilla placodea

(Pore plate sensilla) is characteristic of many bees in particular and is believed to be olfactory in function. It appears oval in shape and has a diameter of 10µm in and distributed on each flagellomeres in varying numbers (Figs. 1b, 2a). We counted on an average 25 sensilla placodea on the distal flagellomeres. However, a reduction in the number of these sensilla was noticed on other flagellomeres indicating a descending pattern in distribution of these sensilla towards the basal flagellomeres.

2. Sensilla basiconica

They projects straight from the antennal surface and are approximately 10µm long with a

sensillar shaft which ends bluntly. Apparently, they are abundantly distributed on the tip and lateral sides of the distal flagellomere (flagellomere 10). However, they are conspicuous by their absence on other flagellomeres.

3a. Sensilla trichodea type 1

This sensilla is approximately 12µm in length with a sensillum shaft that tapers gradually and ends with a sharp tip. The base of the sensilla arises from a circular depression below the antennal surface. We noticed this sensilla on the distal most flagellomeres, however the sensilla was absent on other flagellomeres (Fig. 2a). Generally, these sensilla are considered to be mechano sensory in function.

3b. Sensilla trichodea type 2

These sensilla are present on all flagellomeres. They are approximately 15µm in length and have a shaft that has uniform width throughout its length. The basal part of the shaft arises from a small dome like structure of the antenna surface (Fig. 2a). The structure of these sensilla suggests a mechano receptive function.

3c. Sensilla trichodea type 3

These sensilla are sparsely distributed on the flagellomeres. The most striking feature of these sensilla is the highly curved appearance of their shaft. The sensillum has a length of 12µm and is a putative mechano receptor (Figs. 2a and 2b).

3d. Sensilla trichodea type 4

These sensilla are present abundantly on the distal flagellomere, it is approximately 5µm in length with a shaft of uniform width from its base to the tip (Fig. 2b).

4a. Sensilla trichodea curvata type 1

These sensilla are 3µm in length with a sparse distribution as they are distributed on the flagellomere number 1-3. They appear to be chemosensory (Fig. 3a).

4b. Sensilla trichodea curvata type 2

They are present on all flagellomeres except the 8th and 9th flagellomeres. They have a characteristic curved shape of the sensilla shaft. They are 6µm in length. Unlike other sensilla which are distributed in a single direction on the antenna, sensilla trichodea curvata are found to be oriented in different directions on the antenna (Fig. 3b).



Figure 1: a. Microphotograph of the antenna of *T. iridipennis*; b. enlarged view of the distal flagellomere (Flagellomere no: 10) the arrow indicates the sensilla basiconica. Black dots indicate sensilla placodea. Scale bar: 100 µm for fig. 1a and 50 µm for fig. 1b.

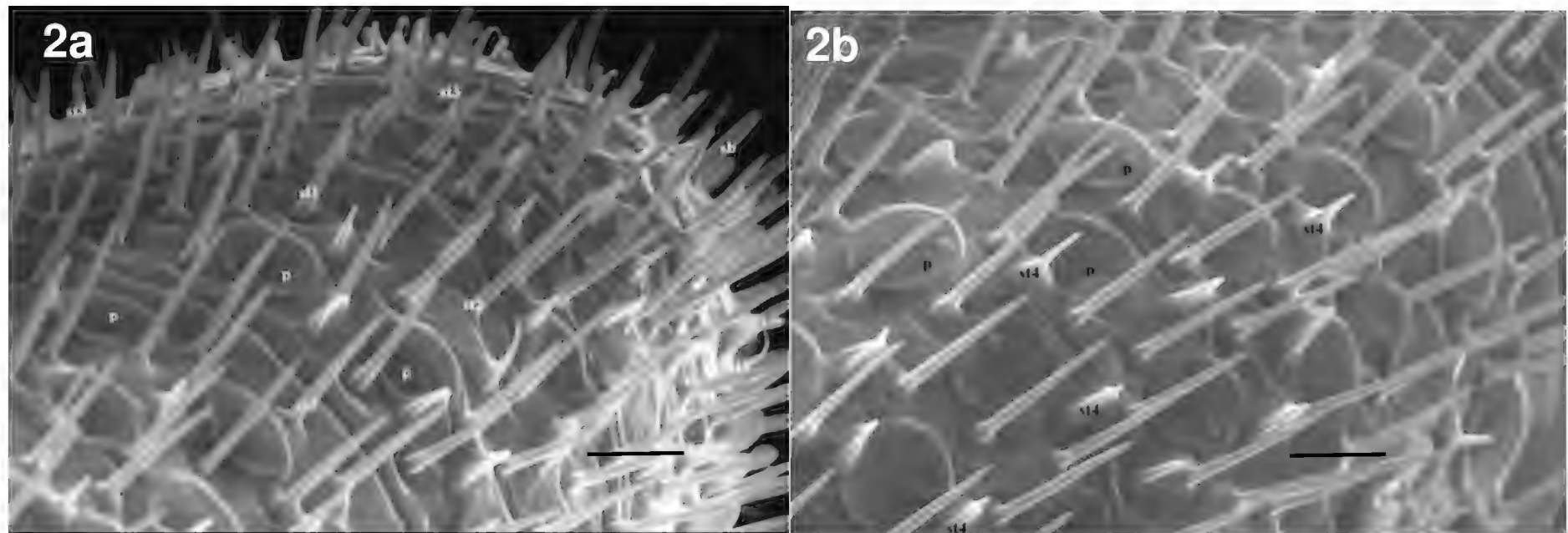


Figure 2: **a.** SEM image of the flagellomere number 10. p- sensilla placodea, st1- sensilla trichodea type 1, st2- sensilla trichodea type 2, st3- sensilla trichodea type 3. sb- sensilla basiconica; **b.** Scanning electron microscope (SEM) image of the flagellomere 9. p- sensilla placodea, st4- sensilla trichodea type 4. Scale bar 10 μm .

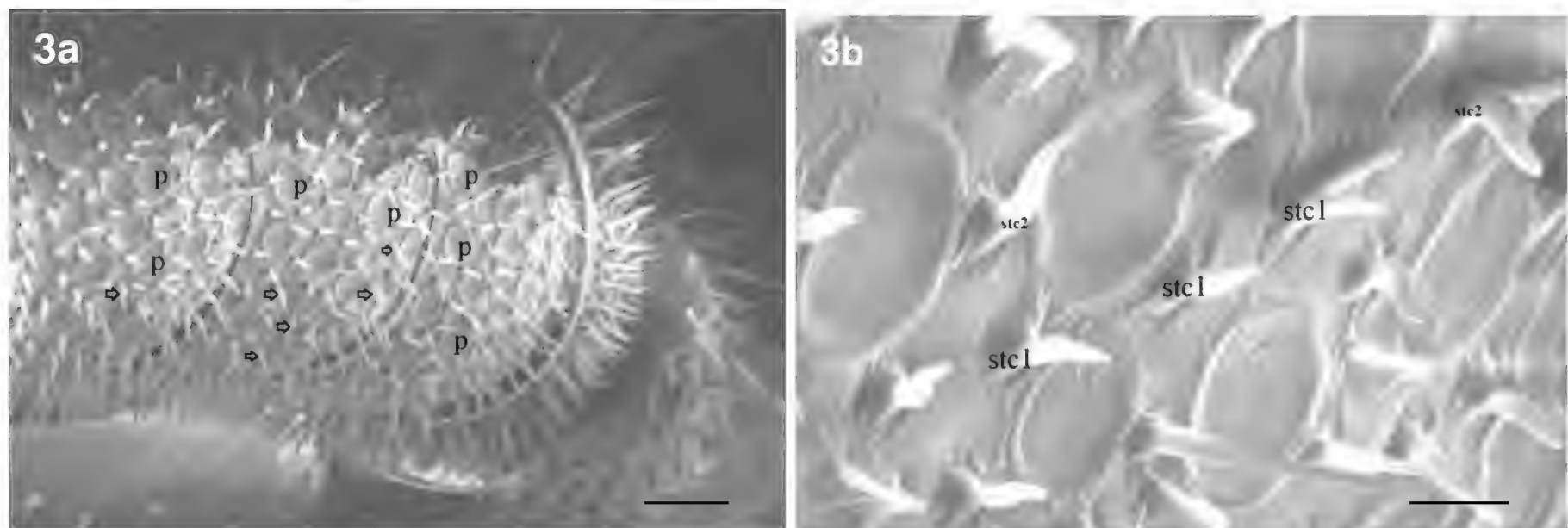


Figure 3: **a.** SEM image of the flagellomere nine of *T. iridipennis*; p- sensilla placodea, arrow indicates sensilla trichodea curvata, st4- sensilla trichodea type 4. Scale bar 20 μm ; **b.** SEM image of the lateral area of the flagellomere number 3, 2 and 1; stc1- sensilla trichodea curvata type 1, stc2-sensilla trichodea curvata type. Scale bar 5 μm .

Table 1: Morphometry of antennal flagellomeres of *T. iridipennis*

Flagellomere number	10	9	8	7	6	5	4	3	2	1
Length (μm)	15	15	8	7	8	8	8	7	7	8
Width (μm)	11	11	11	11	11	11	11	10	10	10

Table 2: Characteristic features of the antennal sensilla of *T. iridipennis*

	Sensilla type	Length diameter (µm)	Morphological features
I	Sensilla basiconica	10	Long, having blunt end with pores on the shaft and tip pore
II	Sensilla trichodea 1	12	Long, straight with pointed tip
	Sensilla trichodea 2	15	Broader base, not very sharp tip
	Sensilla trichodea 3	12	Elongated with curved, prominently pointed tip
	Sensilla trichodea 4 (engraved)	5	Shaft of uniform width
III	Sensilla placodea	10	Oval, flattened, and distributed throughout the flagellomeres
IV	Sensilla trichodea curvata 1	3	Sparse distribution
V	Sensilla trichodea curvata 2	6	Comma shaped with a broad base and tapering and shaft towards the tip

Table 3: Number of sensilla placodea on the flagellomeres

Segment No.	No. of sensilla placodea (pore plates)
1	12±3
2	14±3
3	12±6
4	10±6
5	10±4
6	12±8
7	24±6
8	26±4
9	32±6
10	34±6

Discussion

T. iridipennis shows general patterns to other stingless bees based on the types of sensilla they possess and their distribution on the antenna (Month-Juris *et al.*, 2020). However, significant differences are suggestive of the life style influenced changes (Johnson and Howard, 1987). Distal most flagellomeres of *T. iridipennis* bear (flagellomeres: 10, 9 and 8) the most number of diverse sensilla (Figs.1b, 2a and 2b). We observed that the dorsal part of the distal flagellomeres bear sensilla abundantly compared to other flagellomeres. Further,

sensilla diversity and the total number of sensilla shows a clear pattern of decrease as one goes from the distal most flagellomere to the basal ones towards the scape. Sensilla placodea are the most abundant sensilla on the antenna of *T. iridipennis*, and this seems to be a prominent pattern in the sensilla distribution which has been corroborated from previous studies on different species of stingless bees. However, the absence of sensilla coeloconica and sensilla ampullacea in *T. iridipennis* is noteworthy; these sensilla being hygro receptive and CO₂ receptive and found to be present in many social insect

including some species of stingless bees, their absence in case of *T. iridipennis* indicates difference in the sensory ecology. It is also interesting to note that *T. iridipennis* has a conspicuous reduction in the number of sensilla basiconica on the antenna. Sensilla basiconica is found to be the chief olfactory sensilla of many hymenopterans including ants, and their reduction in numbers suggest a change in the chemo sensory perceptual mechanisms. Sensilla placodea playing the key role as the primary olfactory sensilla in *T. iridipennis* is quite likely.

We could also identify the presence of three unique sensilla on the antenna of *T. iridipennis*, putatively chemo sensory by their appearance: the disheveled sensilla basiconica, the engraved sensilla trichodea and the bifid sensilla. However, electro physiological studies needs to be conducted to ascertain their functional properties.

Sensilla profiles often reflect the sensory ecology of the insects. Our studies suggest that *T. iridipennis* shows many similarities to other stingless bees and in general to other hymenopterans with respect to their antennal sensilla profiles. However, sensilla profile of insects differs in relation to sex, caste and adaptations (Ravaiano *et al.*, 2014). Sensilla profile especially the total sensilla number and the types of sensilla an insect possess are probable reflections of an insects interface with the environment. For example, a comparison of the antennal sensilla of *Drosophila* and honey bees reflects phylogenetic and life style based differences of these insects (Stocker, 1994; Kropf *et al.*, 2014).

The many subtypes of sensilla trichodea types and the absence of sensilla ampullacea and sensilla coeloconica and the presence of very few campaniform sensilla are the prominent features of antenna sensilla profile of *T. iridipennis*. Sensilla placodea are the most abundant one with the highest number of these sensilla observed on the distal most flagellomeres and a consequent reduction in their numbers in the subsequent flagellomeres towards the basal flagellomeres. This is observed to be a common feature of the chemosensilla distribution noticed in many hymenopterans, where a skewed distribution of

certain types of sensilla (Elgar *et al.*, 2018). It is the chemosensory sensilla basiconica which is the most abundant sensilla whereas in many cases of stingless bees it is the sensilla placodea as in the case of *T. iridipennis*.

Acknowledgements

Authors thank Prof. Rajashekhar K Patil, Mangalore University for his great way of mentoring students.

References

- Babu, M.J., Ankolekar, S.M. and Rajashekhar, K.P. 2011. Castes of the weaver ant *Oecophylla smaragdina* (Fabricius) differ in the organization of sensilla on their antennae and mouthparts. Current Science 101: 755–764.
- Carvalho, W.J.D., Fujimura, P.T., Bonetti, A.M., Goulart, L.R., Cloonan, K., da Silva N.M., Araújo, E.C.B., Ueira-Vieira, C. and Leal, W.S. 2017. Characterization of antennal sensilla, larvae morphology and olfactory genes of *Melipona scutellaris* stingless bee. PLoS ONE 12(4): e0174857.
- Chapman, R.F. 1982. Chemoreception: The Significance of Receptor Numbers. Advances in Insect Physiology, Academic Press, Volume 16: 247-356.
- Elgar, M.A., Zhangb, D.,Wanga, Q., Wittwera, B., Hieu Thi Phama, Johnsona, T.L., Freelancea, C.B. and Coquilleau, M. 2018. Insect Antennal Morphology: The Evolution of Diverse Solutions to Odorant Perception. Yale Journal of Biology and Medicine 91: 457-469.
- Fialho, M.C.Q., Guss-Matiello, C.P., Zanuncio, J.C., Campos, L.A.O. and Sero, J.E. 2014. A comparative study of the antennal sensilla in corbiculate bees. Journal of Apicultural Research 53: 391-403.
- Galvani, G.L., González-Vaquero, R.A. and Guerra-Navarro, C. 2017. Antennal sensilla of cleptoparasitic and non-parasitic bees in two subfamilies of Apidae. Apidologie 48: 437.
- Herzner, G., Schmitt, T., Linsenmair, K.E. and Strohm, E. 2003. Flagellar sensilla in male and female European beewolves, *Philanthus triangulum* (Hymenoptera: Sphecidae). Entomologica Fennica 14(4): 1-10.

- 237–247.
- Johnson, L., and Howard, J. 1987. Olfactory Disc Number in Bees of Different Sizes and Ways of Life (Apidae: Meliponinae). *Journal of the Kansas Entomological Society* 60(3): 380-388.
- Kropf, J., Kelber, C., Bieringer, K. and Rössler, W. 2014. Olfactory subsystems in the honeybee: sensory supply and sex specificity. *Cell and Tissue Research* 357(3): 583-595.
- Li, J., Guo, Q., Han, S., Jiang, L. and Liang, G. 2013. Types, Morphologies and Distributions of Antennal Sensilla of *Quadrastichus erythrinae* (Hymenoptera: Eulophidae), *Florida Entomologist* 96(4): 1288–1297.
- Makkar, G.S., Chhuneja, K. and Singh, J. 2018. Stingless Bee, *Tetragonula iridipennis* Smith, 1854. (Hymenoptera: Apidae: Meliponini): Molecular and Morphological characterization. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* 88(1): 285-291.
- Month-Juris, E., Ravaiano, S.V., Lopes, D.M., Fernandes Salomão, T.M. and Martins, G.F. 2020. Morphological assessment of the sensilla of the antennal flagellum in different castes of the stingless bee *Tetragonisca fiebrigi*. *Journal of Zoology* 310(2): 110-125.
- Rahman, A., Das, P.K., Rajkumari, P., Saikia, J. and Sharmah, D. 2015. Stingless Bees (Hymenoptera: Apidae: Meliponini): Diversity and Distribution in India. *International Journal of Science and Research* 4(1): 77–814.
- Rasmussen, C. 2013. Stingless bees (Hymenoptera: Apidae: Meliponini) of the Indian subcontinent: Diversity, taxonomy and current status of knowledge. *Zootaxa* 3647(3): 401–428.
- Ravaiano, S.V., Ferreira, R.D.P., Campos, L.A.D.O. and Martins, G.F. 2014. The antennal sensilla of *Melipona quadrifasciata* (Hymenoptera: Apidae: Meliponini): A study of different sexes and castes. *Naturwissenschaften* 101(8): 603–611.
- Slifer, E.H. and Sekhon, S.S. 1961. Fine structure of the sense organs on the antennal flagellum of the honeybee, *Apis mellifera* Linnaeus. *Journal of Morphology* 109: 351-381.
- Stocker, R.F. 1994. The organization of the chemosensory system in *Drosophila melanogaster*: a review. *Cell and Tissue Research* 275: 3–26.
- Wittwer, B., Hefetz, A., Simon, T., Li, E., Murphy, K., Elgar, M.A., Pierce, N.E. and Kocher, S.D. 2017. Solitary bees reduce investment in communication compared with their social relatives. *Proceedings of the National academy of Sciences* 114(25): 6569–6574.

A Survey of Eulophid Wasps (Hymenoptera: Chalcidoidea) Associated with Rice Ecosystems of Tamil Nadu

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Abstract

Surveys were conducted to explore the eulophid fauna in rice ecosystems of Tamil Nadu during 2015-16 in three different rice-growing zones *viz.*, western zone, Cauvery delta zone and high rainfall zone. In the present study, a total of 161 eulophid individuals were collected from rice ecosystems that represent 3 subfamilies, 8 genera and 14 species. The three subfamilies were Entodoninae, Eulophinae and Tetrastichinae. Alpha and beta diversity were computed for the three zones and the diversity indices (Simpson's index, Shannon-Wiener index, Pielou's index) revealed that the high rainfall zone as the most diverse zone, while western zone being the least. *Aprostocetus benazeer* Narendran was found to be the most abundant species in the rice ecosystem with a relative density of 12.4 per cent. On comparing the species similarities using the Jaccard's index in between the three sites taken in pairs, it was found that 66 per cent similarity between western and Cauvery delta zones and 42 per cent similarity between high rainfall and Cauvery delta zones and 35 per cent similarity between high rainfall and western zones.

Keywords: Diversity, Hymenoptera, Chalcidoidea, Eulophidae, Rice Ecosystem, India.

Received: 2 April 2020; Revised: 30 December 2020; Online: 31 December 2020

Introduction

Rice is one of the most important grains for human nutrition, being the staple food of more than three billion people and cultivated across 112 countries covering every continent except Antarctica (Acosta *et al.*, 2017). Rice fields harbour a rich and varied fauna than any other agricultural crop (Heckman, 1979; Fritz *et al.*, 2011). The fauna is dominated by micro, meso and macro arthropods inhabiting the soil, water and vegetation sub-habitats of the rice fields. The different communities of terrestrial arthropods in the rice field include pests, their natural enemies (predators and parasitoids) and other neutral insects that inhabit or visit the vegetation as tourists (Heong *et al.*, 1991). More than 800 species of insects are known to infest rice, of which about 20 species are of economic importance. Farmers generally rely on insecticides to combat pest problems of rice. Indiscriminate use of insecticides resulted in the loss of biodiversity of beneficial organisms like

parasitic hymenopterans (Dudley *et al.*, 2005). Reducing the mortality of parasitic hymenopterans caused by insecticides is essential for greater sustainability in rice pest management (Heong and Hardy, 2009; Gurr *et al.*, 2011). Parasitic hymenopterans especially eulophids are the best alternatives to pesticides. They show greater stability to the ecosystem than any group of natural enemies of insect pests because they are capable of living and interacting at lower host population level. To aid this means of pest control, it is essential that the diversity of parasitoids needs to be studied first (Dey *et al.*, 1999).

The majority of Eulophidae are primary parasitoids of concealed larvae, especially those inhabiting leaf mines. The best known species attack Lepidoptera, but many species parasitize larvae of other insects living in similar concealed situations (such as Agromyzidae, heterarthrine Tenthredinidae and Curculionidae).

Other eulophids attack various gall-forming species of insects, eriophyid mites (Boucek and Askew, 1968) and also gall-forming nematodes (Berg *et al.*, 1990). Various other species collectively exhibit a great range of lifeways. A number of other eulophids develop as endoparasitoids in insect eggs. The diversity of eulophids associated with rice ecosystem is poorly studied and far from satisfaction especially in Tamil Nadu. Any additional knowledge in diversity, taxonomy and biology is of potential practical value. In this context, the present study was undertaken to explore the diversity of eulophid fauna in rice ecosystems of Tamil Nadu.

Materials and Methods

Sites of collection

The survey was carried out in the rice fields during 2015-16 in three different agro climatic zones of Tamil Nadu State *viz.*, western zone: Paddy Breeding Station, Coimbatore, 427 m, 10° 59' 43.24" N 76° 54' 59.22" E), Cauvery delta zone: Krishi Vigyan Kendra, Needamangalam, 26 m, 10° 46' 23.93" N, 79° 25' 0.96" E) and high rainfall zone: Agricultural Research Station, Thirupathisaram, 17 m, 8° 12' 16.70" N, 77° 26' 57.84" E). Collections were made for 20 consecutive days in each zone to give equal weightage and to minimize chances of variations in the collection. The time of sampling in each zone was decided by the rice growing season of the zone and the stage of the crop *i.e.*, 20 days during August- September, 2015 in western zone, October- November, 2015 in high rainfall zone and December, 2015 – January 2016, in Cauvery delta zone.

Methods of collection

A total of three different gadgets *viz.*, sweep net, yellow pan trap kept at ground level and yellow pan trap erected at canopy levels were employed. All the three gadgets were employed continuously for 20 days.

(a) Sweep Net

The net employed for collection was essentially similar to an ordinary insect net with 673 mm mouth diameter and a 1076 mm long aluminum handle. The frame can be fitted to one end of the handle. This facilitates easy separation of the frame. The long handle allows

the net to be used as far as possible making the sweeping easier and effective. The net bag was made up of thin cotton cloth. It measures about 600 mm in length and has a well rounded bottom. The top of the bag which fits around the frame was made up of a canvas. The canvas was folded over the frame and sewed in position. Sweeping of vegetation was as random as possible from ground level to the height of the crop. Sweeping was done during early morning and late evening hours for about half an hour per day which involved 30 sweeps. One to and fro motion of the sweep net was considered as one sweep.

(b) Yellow pan traps kept at ground level

This trap was based on the principle that many insects are attracted to bright yellow colour. Yellow pan traps are shallow trays of 133 mm × 195 mm and 48 mm deep and were of bright yellow in colour. Altogether, twenty yellow pan traps were installed at ground level in each site on the bunds, half-filled with water containing a few drops of commercially available detergent (to break the surface tension) and a pinch of salt (to reduce the rate of evaporation and to prevent rotting of trapped insects). The spacing between traps was standardized as 1.5 m. The traps were set for a period of 24 hours (Example: traps set at 10 AM on one day were serviced at 10 AM on the following day).

(c) Yellow pan traps erected up to canopy level

Erected yellow pan traps were installed at the crop canopy by means of polyvinyl chloride pipes fitted below, with a screw attachment and were installed in 10 numbers per site in the same fashion as Yellow pan traps kept at ground level.

Preservation and identification of the specimens up to family level:

The parasitoids thus collected were preserved in 70% ethyl alcohol. The dried specimens were mounted on pointed triangular cards and studied under a Stemi (Zeiss) 2000-C and photographed under Leica M205 A stereozoom microscopes and identified through conventional taxonomic techniques by following standard keys. For future references all the identified specimens were submitted in Insect Biosystematics Laboratory, Tamil Nadu

Agricultural University, Coimbatore.

Measurement of diversity

1. Relative Density

Relative density of the species was calculated by the formula, Relative Density (%) = (Number of individuals of one species / Number of individuals of all species) X 100.

2. Alpha Diversity

Alpha diversity of the zones was quantified using Simpson's diversity Index (*SDI*) Shannon-Wiener index (H'), Margalef Index (α) and Pielou's Evenness Index (*EI*).

(a) Simpson's Index

Simpson's diversity index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. It is calculated using the formula, $D = \sum n(n-1)/N(N-1)$ where n = total number of organisms of a particular species and N = total number of organisms of all species (Simpson, 1949). Subtracting the value of Simpson's diversity index from 1, gives Simpson's Index of Diversity (SID). The value of the index ranges from 0 to 1, the greater the value the greater the sample diversity.

(b) Shannon-Wiener Index

Shannon-Wiener index (H') is another diversity index and is given as follows: $H' = -\sum P_i \ln(P_i)$, where $P_i = S/N$; S = number of individuals of one species, N = total number of all individuals in the sample, \ln = logarithm to base e (Shannon & Wiener, 1949). The higher the value of H' , the higher the diversity.

(c) Margalef Index

Species richness was calculated for the three zones using the Margalef index which is given as Margalef Index, $\alpha = (S - 1) / \ln(N)$; S = total number of species, N = total number of individuals in the sample (Margalef, 1958).

(d) Pielou's Evenness Index

Species evenness was calculated using the Pielou's Evenness Index (*EI*). Pielou's Evenness Index, $EI = H' / \ln(S)$; H' = Shannon-Wiener diversity index, S = total number of species in the sample (Pielou, 1966). As species richness and evenness increases, diversity also increases (Magurran, 1988).

3. Beta Diversity

Beta diversity is a measure of how different (or similar) ranges of habitats are in terms of the variety of species found in them. The most widely used index for assessment of Beta diversity is Jaccard Index (JI) (Jaccard, 1912), which is calculated using the equation: JI (for two sites) = $j/(a+b-j)$, where j = the number of species common to both sites A and B, a = the number of species in site A and b = the number of species in site B. We assumed the data to be normally distributed and adopted parametric statistics for comparing the sites.

Statistical analysis

The statistical test ANOVA was also used to check whether there was any significant difference in the collections from three zones. The data on population number were transformed into $X+0.5$ square root before statistical analysis. The mean individuals caught from three different zones were analyzed by adopting Randomized block design (RBD) to find least significant difference (LSD). Critical difference (CD) values were calculated at five per cent probability level. All these statistical analyses were done using Microsoft Excel 2016 version and Agres software version 3.01.

Results and Discussion

In the present study, a total of 161 eulophid individuals were collected from rice ecosystems that represent 3 subfamilies, 8 genera and 14 species. The three sub families are Entodoninae, Eulophinae and Tetrastichinae. Altogether 8 species were collected and identified under the subfamily Tetrastichinae viz., *Aprostocetus benazeer* Narendran, *A. harithus* Narendran, *A. malcis* Narendran, *Tetrastichus cupressi* Yang, *T. krishnieri* (Mani), *T. schoenobii* Ferriere, *T. howardi* (Oloff), and *T. tunicus* Narendran. Under the subfamily Eulophinae, four species were collected and identified viz., *Euplectrophelinus* sp., *Hemiptarsenus* sp. and *Necremnus leucarthros* (Nees) and *Elasmus kollimalaianus* Mani. Under the sub family Entedoninae, *Closterocerus* sp. and *Pediobius inexpectatus* Kerrich were the two species collected in the present study. As on date, thirty-two species of eulophids were collected form rice ecosystems throughout India. Of which, *Euplectrophelinus*

sp., *Hemiptarsenus* sp., *Necremnus leucarthros*, *Tetrastichus cupressi* and an undetermined species under the genera *Tetrastichus* were new additions (Daniel and Ramaraju, 2019).

The survey results revealed that the species richness was maximum (12) in high rainfall zone. The number of species collected from western and Cauvery delta zones was 07 and 08, respectively (Table 1). A total of 97, 41 and 23 eulophids were collected from high rainfall, western and Cauvery delta zones, respectively. *Aprostocetus benazeer* was found to be the most abundant species in the rice ecosystem with a relative density of 12.4 per cent. Species such as *A. benazeer*, *A. harithus*, *A. malicis*, *Closterocerus* sp. and *T. tunicus* were obtained only from high rainfall zone. Species such as *E. kollimalaianus*, *Euplectrophelinus* sp., *P. inexpectatus* and *T. cupressi* were common to all the three zones surveyed. *Hemiptarsenus* sp. and *N. leucarthros* were common to both western and Cauvery delta zones. Only one species named *T. howardi* was found common to both western and high rainfall zones. Two species viz., *T. krishnieri* and *T. schoenobii* were collected from Cauvery delta and high rainfall zones. *Tetrastichus cupressi*, *T. krishnieri* and *A. benazeer* were found to be predominant in western, Cauvery delta and high rainfall zones, with a relative density of 29.3, 30.4 and 20.6 per cent, respectively. The occurrence of four species viz., *A. benazeer*, *Closterocerus* sp., *P. inexpectatus* and *T. cupressi* were found to significantly differ between the zones as tested by ANOVA.

Among the three zones, more number of eulophids was collected from high rainfall zone with a mean number of 4.85 ± 1.04 eulophids per day. It is statistically superior to the western and the Cauvery delta zones which have a mean number of 2.05 ± 0.60 and 1.15 ± 0.39 eulophids per day, respectively (Table 2). The Simpson's index of Diversity was the highest for high rainfall zone (0.87), followed by Cauvery delta zone (0.84) and western zone (0.83). Similar trend was observed in Shannon-Wiener index also with 0.78, 0.79 and 0.94 for western, Cauvery delta and high rainfall zones, respectively. The values of Margalef index for the three zones revealed that maximum richness (2.40) was accounted for high rainfall zone

followed by Cauvery delta zone (2.23) and western zone (1.16). The species evenness was maximum for western zone (0.40) and for the Cauvery delta and high rainfall zones, it was 0.37 and 0.38, respectively. On comparing the species similarities using the Jaccard's index in between the three sites taken in pairs, it was found that 66 per cent similarity between western and Cauvery delta zones and 42 per cent similarity between high rainfall and Cauvery delta zones and 35 per cent similarity between high rainfall and western zones. The host details of the all the collected Eulophids are tabulated (Table. 3). The fourteen species of eulophids that were collected are also presented (Plate 1).

Daniel *et al.* (2017, 2019b and 2020) obtained similar results by conducting experiments to assess the diversity of pteromalids, braconids and ichneumonids of rice ecosystems in Tamil Nadu. The species composition among elevational zones can indicate how community structure changes with biotic and abiotic environmental pressures (Shmida and Wilson, 1985; Condit *et al.*, 2002). Studies on the effect of elevation on species diversity of taxa such as spiders (Sebastian *et al.*, 2005), moths (Axmacher & Fiedler, 2008), paper wasps (Kumar *et al.*, 2008) and ants (Smith *et al.*, 2014) reported that species diversity decreased with increase in altitude. However, according to Janzen (1976), diversity of parasitic Hymenoptera is not as proportionately reduced by elevation as in other insect groups, a fact that is in support of our results. A similar study conducted by Shweta and Rajmohana, 2016 to assess the diversity of members belonging to the subfamily Scelioninae also declared that the elevation did not have any major effect on the overall diversity patterns. The elevational diversity gradient (EDG) in ecology proposes that species richness tends to increase as elevation increases, up to a certain point creating "diversity bulge" at moderate elevations (McCain and Grytnes, 2010). The elevation dealt with in this work ranged from 17-427 m which was not very high. So taking into account the scale and extent of elevational gradients, it can be said that species diversity and richness have not showed any correlation i.e. species diversity and richness were not proportional with that of elevation. Daniel and

Table 1. Comparison of Eulophidae collected from three rice growing zones of Tamil Nadu

Species	Zones						Total			
	Western		Cauvery Delta		High Rainfall					
	No.	%	No.	%	No.	%	No.	%	F	P
<i>Aprostocetus benazeer</i>	0	0.0	0	0.0	20	20.6	20	12.4	9.5	0.00
<i>Aprostocetus harithus</i>	0	0.0	0	0.0	4	4.1	4	2.5	2.9	0.06
<i>Aprostocetus malcis</i>	0	0.0	0	0.0	8	8.2	8	5.0	3.23	0.04
<i>Closterocerus</i> sp.	0	0.0	0	0.0	19	19.6	19	11.8	7.00	0.00
<i>Elasmus kollimalaianus</i>	6	14.6	1	4.3	3	3.1	10	6.2	1.31	0.27
<i>Euplectrophelinus</i> sp.	9	22.0	3	13.0	4	4.1	16	9.9	3.12	0.05
<i>Hemiptarsenus</i> sp.	4	9.8	1	4.3	0	0.0	5	3.1	0.76	0.47
<i>Necremnus leucarthros</i>	2	4.9	2	8.7	0	0.0	4	2.5	0.50	0.60
<i>Pediobius inexpectatus</i>	5	12.2	1	4.3	12	12.4	18	11.2	3.75	0.02
<i>Tetrastichus cupressi</i>	12	29.3	2	8.7	3	3.1	17	10.6	3.18	0.04
<i>Tetrastichus krishnieri</i>	0	0.0	7	30.4	6	6.2	13	8.1	1.96	0.14
<i>Tetrastichus schoenobii</i>	0	0.0	6	26.1	1	1.0	7	4.3	2.64	0.07
<i>Tetrastichus howardi</i>	3	7.3	0	0.0	2	2.1	5	3.1	1.52	0.22
<i>Tetrastichus tunicus</i>	0	0.0	0	0.0	15	15.5	15	9.3	1.50	0.23
Total No. collected	41	-	23	-	97	-	161	-	-	
Species Number	07	-	08	-	12	-	14	-		

%- Relative Density, No.- Total number of individuals collected, F-Value, P-Value

Table 2. Diversity indices of Eulophidae from three rice growing zones of Tamil Nadu

Zones	Mean No. of Eulophidae collected/day	Std. Error	SID	H'	α	El	β %
Western	2.05 (1.41) ^b	± 0.60	0.83	0.78	1.61	0.40	W and C – 66
Cauvery Delta	1.15 (1.15) ^b	± 0.39	0.84	0.79	2.23	0.37	C and H - 42
High Rainfall	4.85 (2.12) ^a	± 1.04	0.87	0.94	2.40	0.38	H and W - 35
S.ED	0.23	-	-	-	-	-	-
CD (p=0.05)	0.48	-	-	-	-	-	-

*Figures in parentheses are square root transformed values; In a column, means followed by a common letter(s) are not significantly different by LSD (p=0.05).

*SID- Simpson's Index of Diversity, H'- Shannon-Wiener Index, α - Margalef index, El- Pielou's index, β -Beta diversity (Jaccard Index).

*W- Western Zone, C- Cauvery Delta Zone, H- High Rainfall Zone

Table 3. Eulophidae collected in the study along with their host

Parasitoid	Host	Reference
<i>Aprostocetus benazeer</i>	Cicadellidae	Noyes, 2003
<i>Aprostocetus harithus</i>	Delphacidae	
<i>Aprostocetus malcis</i>	Gryllidae	
	Dytiscidae	
<i>Closterocerus</i> sp.	Agromyzidae	Edwards and La Salle, 2004
<i>Elasmus kollimalaianus</i>	Primary external parasitoids of the larvae of Lepidoptera or hyperparasitoids on them through various Hymenoptera	Gauthier <i>et al.</i> , 2000

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<i>Euplectrophelinus</i> sp.	Unknown	
<i>Hemiptarsenus</i> sp.	Agromyzidae	Thu and Ueno, 2002
<i>Necremnus leucarthros</i>	Chrysomelidae	Dosdall <i>et al.</i> , 2007
<i>Pediobius inexpectatus</i>	Nymphalidae	Purnamasari and Ubaidillah, 2007
<i>Tetrastichus cupressi</i>	Eggs of Lepidoptera	Yang, 2006
<i>Tetrastichus krishnieri</i>		
<i>Tetrastichus schoenobii</i>		
<i>Tetrastichus howardi</i>		
<i>Tetrastichus tunicus</i>		



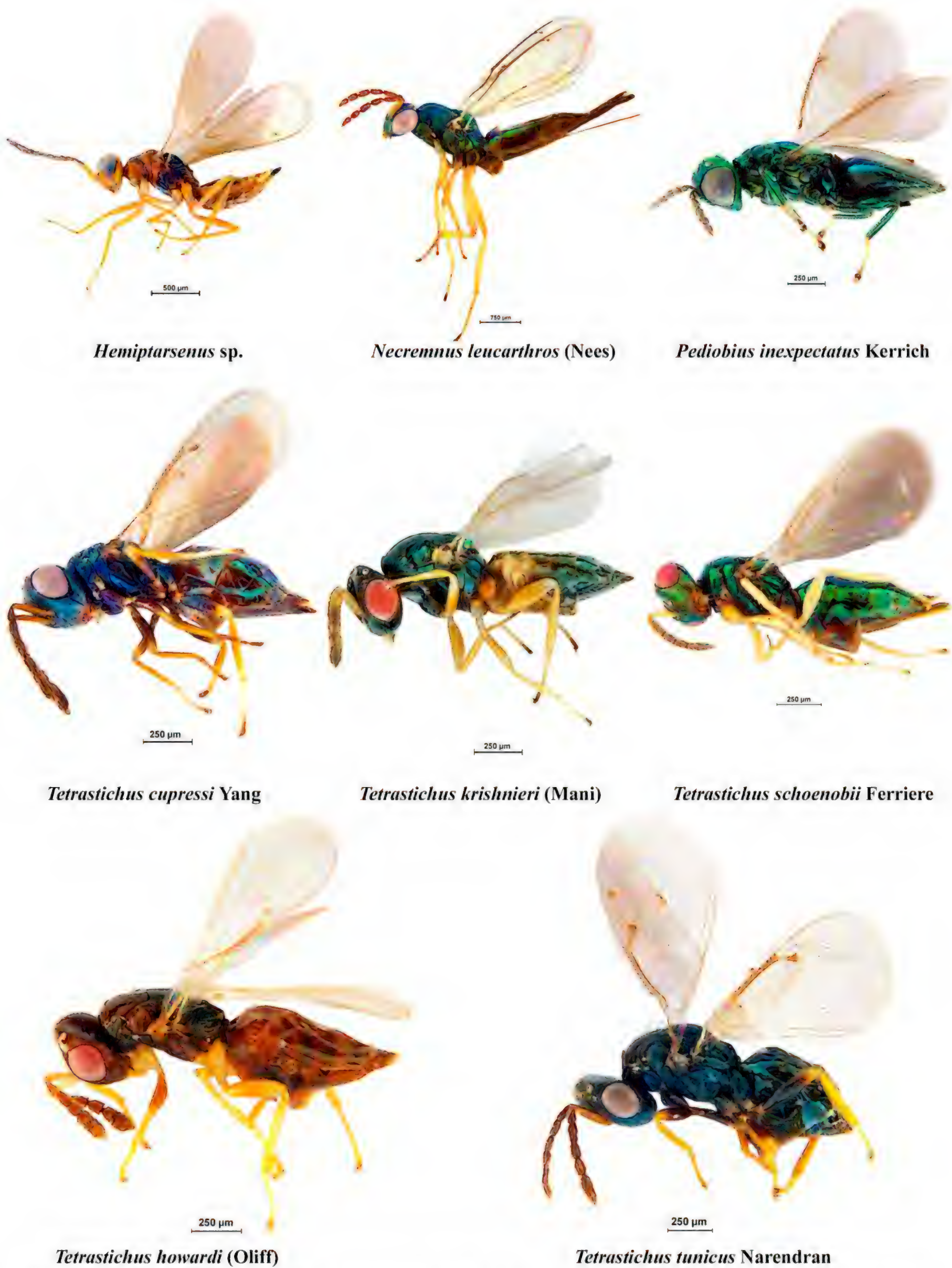


Plate 1. Fourteen species of Eulophidae collected from three rice growing zones of Tamil Nadu

Ramaraju (2017; 2020a & b) assessed the diversity of Chalcididae, Platygastroidea and parasitic Aculeatea, among three rice growing tracts of Tamil Nadu and concluded that there was no correlation between elevation and species richness. This fact supports our present study.

Studies on the altitudinal variation of parasitic Hymenoptera assemblages in an Australian sub-tropical rainforest by Hall *et al.* (2015) did not record any distinct assemblage at each altitude, at the morphospecies level, even though there was a clear separation between ‘upland’ and ‘lowland’ assemblages. To detect minute changes in species assemblages, species level sorting is found to give the best result (Grimbacher *et al.*, 2008). The area under cultivation turns out to be a very important factor with respect to abundance and species density in rice fields (Wilby *et al.*, 2006). The number of species in a habitat increases with increase in area (Gotelli and Graves, 1996). Only few studies have demonstrated the importance of different varieties in attracting the natural enemies (Scutareanu *et al.*, 1997; De Moraes *et al.*, 1998; Thaler, 1999; Kessler and Baldwin, 2001; Lou *et al.*, 2005; Rasmann *et al.*, 2005; Daniel *et al.*, 2019a, d). Lack of success in biological control programs has often been caused by high mortality of parasitoids due to climatic extremes (Daniel *et al.*, 2019c). Therefore, more researches like this should be encouraged to understand the underpinnings between varietal preferences, climatic conditions and parasitoid diversity.

Conclusion

This study reveals the diversity of eulophids of three different rice ecosystems of Tamil Nadu. The reasons for the significant changes in diversity of these parasitoids and their host insects are to be further studied. There is much scope for research to be taken on these aspects.

Acknowledgment

Thanks are due to Ministry of Minority Affairs, Government of India for the financial grants through Maulana Azad National Fellowship.

References

- Acosta, L.G., Jahnke, S.M., Redaelli, L.R. and Pires, P.R.S. 2017. Insect diversity in organic rice fields under two management systems of levees vegetation. *Brazilian Journal of Biology* 77(4): 731-744.
- Axmacher, J.C. and Fiedler, K. 2008. Habitat type modifies geometry of elevational diversity gradients in Geometrid moths (Lepidoptera: Geometridae) on Mt. Kilimanjaro, Tanzania. *Tropical Zoology* 21: 243–251.
- Berg, E. van den, Prinsloo, G.L. and Naser, S. 1990. An unusual host association: *Aprostocetus* sp. (Eulophidae), a hymenopterous predator of the nematode *Subanguina mobilis*. *Phytoparasitica* 22: 125-127.
- Boucek, Z. and Askew, R.R. 1968. Palaearctic Eulophidae sine Tetrastichinae. In: V. Delucchi and G. Remaudière. (Eds.) *Index of Entomophagous Insects* 3 Le François, Paris. 260pp.
- Condit, R., Pitman, N., Leigh, E.G., Chave, J., Terborgh, J., Foster, R.B., Nunez, P., Aguilar, S., Valencia, R., Villa, G., Muller-landau, H.C., Losos, E. and Hubbell, S.P. 2002. Beta diversity in tropical forest trees. *Science* 295: 666–669.
- Daniel, J.A. and Ramaraju, K. 2017. Diversity of chalcidids (Chalcididae: Hymenoptera) among three rice growing zones of Tamil Nadu, India. *Journal of Entomology and Zoology Studies* 5(3): 541-546.
- Daniel, J.A. and Ramaraju, K. 2019. List of Parasitic Hymenopterans Recorded from Rice Ecosystems of India. *Journal of Experimental Zoology India* 22(2): 877-889.
- Daniel, J.A. and Ramaraju, K. 2020a. Platygastroidea from rice ecosystems of Tamil Nadu. *Indian Journal of Entomology* 82(4): 813-818.
- Daniel, J.A. and Ramaraju, K. 2020b. Collecting parasitic Aculeata (Hymenoptera) from rice ecosystems of Tamil Nadu, India. *Journal of Threatened Taxa* 12(8): 15828-15834.
- Daniel, J.A., Ramaraju, K. and Ranjith, A.P. 2019b. On a collection of braconidae from three rice growing zones of Tamil Nadu. *Indian Journal of Entomology* 81(1): 18-24.
- Daniel, J.A., Ramaraju, K., Kumar, S.M., Jeyaprakash, P. and Chitra, N. 2019a. Study

- on varietal preferences and seasonal incidence of parasitoids of rice pests. *Entomon* 44(1): 65-72.
- Daniel, J.A., Ramaraju, K., Kumar, S.M., Jeyaprakash, P. and Chitra, N. 2019c. Influence of weather on the parasitoid catches in three rice growing agroclimatic zones of Tamil Nadu. *Indian Journal of Entomology* 81(1): 55-60.
- Daniel, J.A., Ramaraju, K., Poorani, J. and Nikhil, K. 2019d. Comparison of Eurytomidae and Eupelmidae (Hymenoptera: Chalcidoidea) diversity from three rice growing zones of Tamil Nadu. *Madras Agricultural Journal* 106: 242-248.
- Daniel, J.A., Ramaraju, K., Raseena Farsana, V.K. and Sureshan. P.M. 2017. Diversity of Pteromalids (Pteromalidae: Hymenoptera) among three rice growing Zones of Tamil Nadu, India. *Annals of Plant Protection Sciences* 25(2): 298-303.
- Daniel, J.A., Ramaraju, K., Sudheer, K. and Vishnu, K. 2020. Ichneumonid fauna associated with rice ecosystems of Tamil Nadu, India. *Journal of Biological Control* 34(1): 15-20.
- De-Moraes, C.M., Lewis, W.J., Pare, P.W. and Tumlinson, J.H. 1998. Herbivore- infested plants selectively attract parasitoids. *Nature* 393: 570-573.
- Dey, D., Raghuraman, M., Gupta, S.L. and Ramamurthy, V.V. 1999. A checklist of the biodiversity of hymenopterous parasitoids associated with rice agroecosystem. *Shashpa* 1: 1-128.
- Dosdall, L.M., Gibson, G.A.P., Olfert, O., Keddie, B.A. and Ulmer, B.J. 2007. Contributions to the life history, host range, and distribution of *Necremnus tidius* (Hymenoptera: Eulophidae). *Annals of the Entomological Society of America* 100(6): 861-868.
- Dudley, N., Baldock, D., Nasi, R. and Stolton, S. 2005. Measuring biodiversity and sustainable management in forests and agricultural landscapes. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 360(1454): 457-470.
- Edwards, C.M. and La Salle, J. 2004. A new species of *Closterocerus* Westwood (Hymenoptera: Eulophidae), a parasitoid of serpentine leafminers (Diptera: Agromyzidae) from Australia. *Australian Journal of Entomology* 43(2):129-132.
- Fritz, L.L., Heinrichs, E.A., Machado, V., Andreis, T.F., Pandolfo, M., Salles, S.M. and Oliveira, J.V. and Fiuza, L.M. 2011. Diversity and abundance of arthropods in subtropical rice growing areas in the Brazilian south. *Biodiversity Conservation* 20(10): 2211-2224.
- Gauthier, N., LaSalle, J., Quicke, D.L.J. and Godfray, H.C.J. 2000. Phylogeny of Eulophidae (Hymenoptera: Chalcidoidea), with a reclassification of Eulophidae and the recognition that Elasmidae are derived eulophids. *Systematic Entomology* 25: 521-539.
- Gotelli, N.J. and Graves, G.R. 1996. *Null Models in ecology*. Washington and London: Smithsonian Institution Press. 359 pp.
- Grimbacher, P.S., Catterall, C.P. and Kitching, R.L. 2008. Detecting the effects of environmental change above the species level with beetles in a fragmented tropical rainforest landscape. *Ecological Entomology* 33: 66-79.
- Gurr, G.M., Liu, J. and Read, D.M.Y. 2011. Parasitoids of Asian rice planthopper (Hemiptera: Delphacidae) pests and prospects for enhancing biological control. *Annals of Applied Biology* 158: 149-176.
- Hall, C.R., Burwell, C.J., Nakamura, A. and Kitching, R.L. 2015. Altitudinal variation of parasitic Hymenoptera assemblages in Australian subtropical rainforest. *Australian Entomology* 54: 246-258.
- Heckman, C.W. 1979. Rice field ecology in North East Thailand. *Monographs Biology* 34: 228.
- Heong, K.L., Aquino, G.B. and Barrion A.T. 1991. Arthropod community structures of rice ecosystems in the Philippines. *Bulletin of Entomological Research* 81: 407-416.
- Heong, K.L. and Hardy, B. 2009. *Planthoppers: New Threats to the Sustainability of Intensive Rice Production Systems in Asia*. Philippines: International Rice Research Institute 257-280 pp.
- Jaccard, P. 1912. The distribution of the flora in the alpine zone. *New Phytologist* 11: 37-50.

- Janzen, D.H. 1976. Changes in the arthropod community along an elevational transect in the Venezuelan Andes. *Biotropica* 8: 193–203.
- Kessler, A. and Baldwin, I.T. 2001. Defensive function of herbivore-induced plant volatile emissions in nature. *Science* 291: 2141–2144.
- Kumar, A., Longino, J.T., Colwell, R.K. and Donnell, S.O. 2008. Elevational patterns of diversity and abundance of Eusocial paper wasps (Vespidae) in Costa Rica. *Biotropica* 41: 338–346.
- Lou, Y., Du, M., Turlings, T.C.J., Cheng, J. and Shan, W. 2005. Exogenous application of jasmonic acid induces volatile emissions in rice and enhances parasitism of *Nilaparvata lugens* eggs by the parasitoid *Anagrus nilaparvatae*. *Journal of Chemical Ecology* 31: 1985–2002.
- Magurran, E.A. 1988. *Ecological Diversity and its Measurement*. Croom Helm, Australia: Springer. 215pp.
- Margalef, R. 1958. Temporal succession and spatial heterogeneity in phytoplankton, In: *Perspectives in Marine Biology*. Berkeley: University of California Press. 323–347 pp.
- Noyes, J.S. 2003. Universal Chalcidoidea Database. World Wide Web electronic publication Last update 06/2006, www.nhm.ac.uk/entomology/Chalcidoids/index.html.
- Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology* 13: 131–144.
- Purnamasari, H. and Ubaidillah, R. 2007. Notes on Parasitic Wasp Genus *Pediobius* Walker (Hymenoptera: Eulophidae) of Java-Indonesia, with Five New Records. *Treubia* 35: 117–136.
- Rasman, S., Kollner, T.G., Degemhardt, J., Hiltbold, I., Topfer, S., Kuhlmann, U. and Turlings, T.C.J. 2005. Recruitment of entomopathogenic nematodes by insect-damaged maize roots. *Nature* 434: 732–737.
- Scutareanu, P., Drukker, B., Bruin, J. and Sabelis, M.V. 1997. Volatiles from *Psylla*-infested pear trees and their possible involvement in attraction of anthocorid predators. *Journal of Chemical Ecology* 23: 2241–2260.
- Sebastian, P.A., Mathew, M.J., Beevi, S.P., Joesph, J. and Biju, C.R. 2005. The spider fauna of the irrigated rice ecosystem, in central Kerala, India. *The Journal of Arachnology* 33: 247–255.
- Shannon, C.E. and Wiener, W. 1949. *The Mathematical Theory of Communication*. Urbana: University of Illinois Press. 177pp.
- Shmida, A. and Wilson, M.V. 1985. Biological determinants of species diversity. *Journal of Biodiversity* 12: 1–20.
- Shweta, M. and Rajmohana, K. 2016. Egg parasitoids from the subfamily Scelioninae (Hymenoptera: Platygasteridae) in irrigated rice ecosystems across varied elevational ranges in southern India. *Journal of Threatened Taxa* 8(6): 8898–8904.
- Simpson, E.H. 1949. Measurement of species diversity. *Nature* 163: 688.
- Smith, M.A., Hallwachs, W. and Janzen, D.H. 2014. Diversity and phylogenetic community structure of ants along a Costa Rican elevational gradient. *Ecography* 37: 1–12.
- Thaler, J.S. 1999. Jasmonate-inducible plant defences cause increased parasitism of herbivores. *Nature* 399: 686–688.
- Thu, G.H.T. and Ueno, T. 2002. Biology of *Hemiptarsenus varicornis* (Hymenoptera: Eulophidae), a parasitoid wasp of the leafminer *Liriomyza trifolii* (Diptera: Agromyzidae). *Journal of the faculty of Agriculture, Kyushu University* 47(1): 45–54.
- Wilby, A., Lan, L.P., Heong, K.L., Huyen, N.P.D., Quang, N.H., Minh, N.V. and Thomas, M.B. 2006. Arthropod diversity and community structure in relation to land use in the Mekong Delta, Vietnam. *Ecosystems* 9: 538–549.
- Yang, Z., Strazanac, J.S., Yao, Y. and Wang, X. 2006. A new species of emerald ash borer parasitoid from China belonging to the genus *Tetrastichus* Haliday (Hymenoptera: Eulophidae). *Proceedings of the Entomological Society of Washington* 108(3): 550–558.

A checklist of long horn beetles (Coleoptera: Cerambycidae) of Lumami, Zunheboto District, Nagaland with 23 new records

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Abstract

A checklist of long horn beetles (Coleoptera: Cerambycidae) within the geographical area of Lumami under Zunheboto District, Nagaland is provided. As per the current checklist there are 36 long horn beetle species classified under 31 genera, 18 tribes and 3 sub-families (Prioninae, Cerambycinae and Lamiinae); of which 23 species are new records for the state of Nagaland. For each species, accepted nomenclature followed by all relevant works reporting systematic classification and distribution within and outside India is provided. The checklist is based on specialized literature sources, collections and faunistic researches made by the authors.

Keywords: *Cerambycidae, long horn beetles, Lumami, Nagaland, new record, Zunheboto.*

Received: 11 June 2020; Revised: 30 December 2020; Online: 31 December 2020

Introduction

The representatives of the family Cerambycidae are commonly known as longhorn beetles and can be easily recognised from other families of Coleoptera by its elongated and somewhat parallel-sided body, long antennae and pseudo tetramorous tarsi. With more than 36,000 described species in more than 5000 genera from eight subfamilies, Cerambycidae is one of the biggest families of Coleoptera (Monne *et al.*, 2017). However, in spite of having immense economic and ecological importance, the family is one of the least studied in India (Kariyanna *et al.*, 2017). Similarly, even though Nagaland is recognized as one of the major biodiversity hotspot (Indo-Burma) region of the World (supporting different unique floral and faunal species association), faunal diversity especially Cerambycidae is least studied. Except for faunistic information of Coleoptera belonging to 7 families i.e., Silvanidae, Inopeplidae, Erotylidae, Endomychidae, Monotomidae, Discolomidae and Languriidae (Anonymous, 2005); and systematic account of 19 species by Mitra *et al.* (2016) and a mention of 4 species by Mozhui *et al.* (2017), no proper documentation is available within the state of Nagaland. The present study is therefore, an

effort to present the distribution and diversity of long horn beetles within the geographical area of Lumami in Zunheboto District, Nagaland.

Materials and Methods

a) Study Area:

Sharing international border with Myanmar, Nagaland is a mountainous state in North-East India. The state harbours rich faunal diversity including various species of insects; however, the region is understudied as many areas are difficult to access due to poor road connectivity. Lumami is located at 26.20°N and 94.47°E and 942 meters above sea level (Fig. 1) and with its unique geographical location, the region hosts variety of habitats. With semi-evergreen forest, the area is dominated by *Abroma augusta* (L.) L.f., *Bauhinia variegata* (L.) Benth., *Callicarpa arborea* Roxb., *Duabanga grandiflora* (Roxb. ex DC.) Walpers, *Ficus racemosa* L., *Lagerstroemia speciosa* (L.) Pers., Oak trees (*Quercus griffithii* Hook.f. & Thomson ex Miq. and *Quercus serrata* Murray), *Prunus cerasoides* Buch. -Ham. ex D.Don, *Schima wallichii* (DC.) Korth. and

Terminalia myriocarpa van Heurck & Müll. Arg.

b) Methodology:

The specimens were collected from Lumami during 2014 to 2020. The specimens were collected from trees, flowers, leaves and wooden logs involving various collection

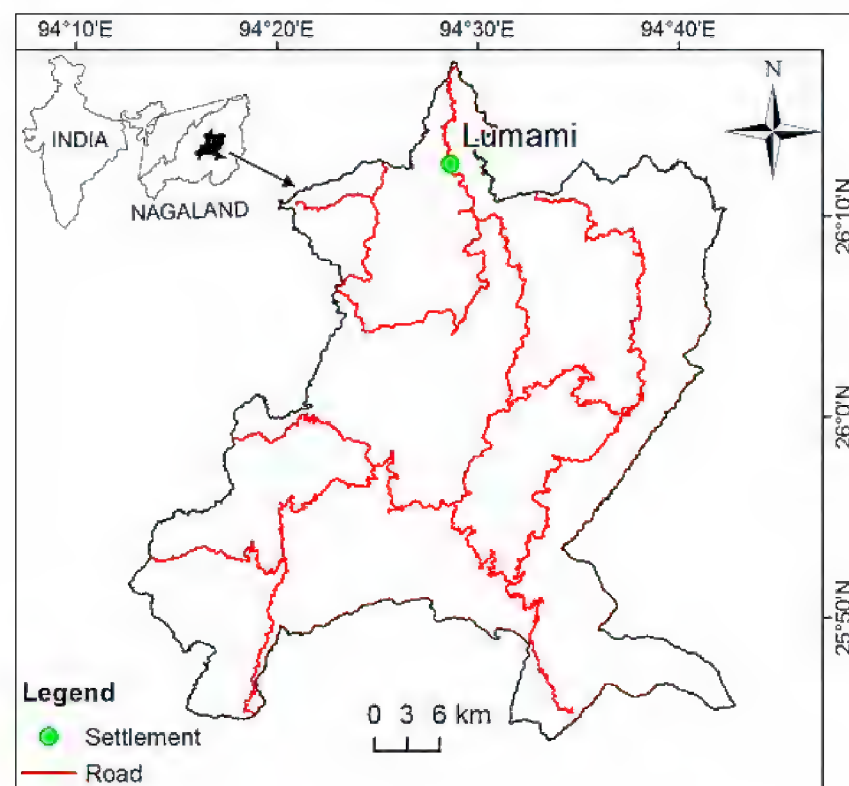


Figure 1: Location of Lumami (Zunheboto district), Nagaland (Source: Survey of India toposheets)

methods and picked carefully with the help of forceps; after which they were gently placed in a jar and killed with the help of benzene (Chandra *et al.*, 2015). They were then brought to the laboratory where the collected specimens were first properly relaxed and pinned and oven dried. The specimens were examined under Labomed CZM6 stereo zoom microscope, photographed with Nikon DSLR D5200 and labeled with Adobe Photoshop v7.0. The specimens were identified using relevant books and literatures (Gahan, 1906; Beeson and Bhatia, 1939; Breuning, 1964; Cherepanov, 1990; Mukhopadhyay and Biswas, 2000a, b; Shylesha *et al.*, 2004; Mukhopadhyay and Halder, 2004; Komiya and Drumont, 2010; Agarwala and Bhattacharjee, 2012; Mitra *et al.*, 2016a, b, c; Kariyanna *et al.*, 2017; Monné *et al.*, 2017; Behere *et al.*, 2019) and were compared with reference collections from Zoological Survey of India, North Eastern Regional Centre, Shillong.

Results

The present study reports a total of 36 species belonging to 31 genera of 18 tribes under 3 sub-families described below (Plate 1-

4). Earlier reports of long horn beetles from Nagaland as well as 23 new records are mentioned in the remarks for each species.

Checklist of Collected Specimens

Systematic Account

Subfamily: Prioninae Latreille, 1802

Tribe: Aegosomatini Thomson, 1861

1. *Baralipion maculosum* (Thomson, 1857)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-01(1)/2014).

Antennae: 10 segments; Body length: 35 mm; Head: 15 mm.

Distribution: India: Arunachal Pradesh, Assam, Sikkim and West Bengal (Kolkata); *Elsewhere:* China (Yunnan), Laos, Myanmar, Thailand and Vietnam.

Remark: First record from Nagaland.

2. *Nepiodes bowringi* (Gahan, 1894)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-02(1)/2014).

Antennae: 10 segments; Body length: 15 mm; Head: 5 mm.

Distribution: India: Arunachal Pradesh, Assam, Nagaland and Sikkim; *Elsewhere:* Myanmar and Nepal.

Remark: Reported in Mitra *et al.*, 2016a; 2017.

3. *Nepiodes costipennis* (White, 1853)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-03(1)/2014).

Antennae: 10 segments; Body length: 13 mm; Head: 6 mm.

Distribution: India: Arunachal Pradesh, Assam, Manipur, Nagaland, North India, Sikkim and West Bengal; *Elsewhere:* China (Sichuan, Xizang, Yunnan), Bangladesh, Myanmar, Nepal and Pakistan.

Remark: Reported in Mitra *et al.*, 2016a, 2017.

Tribe: Macrotomini Thomson, 1860

4. *Bandar pascoei* (Lansberge, 1884)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-04(1)/2014).

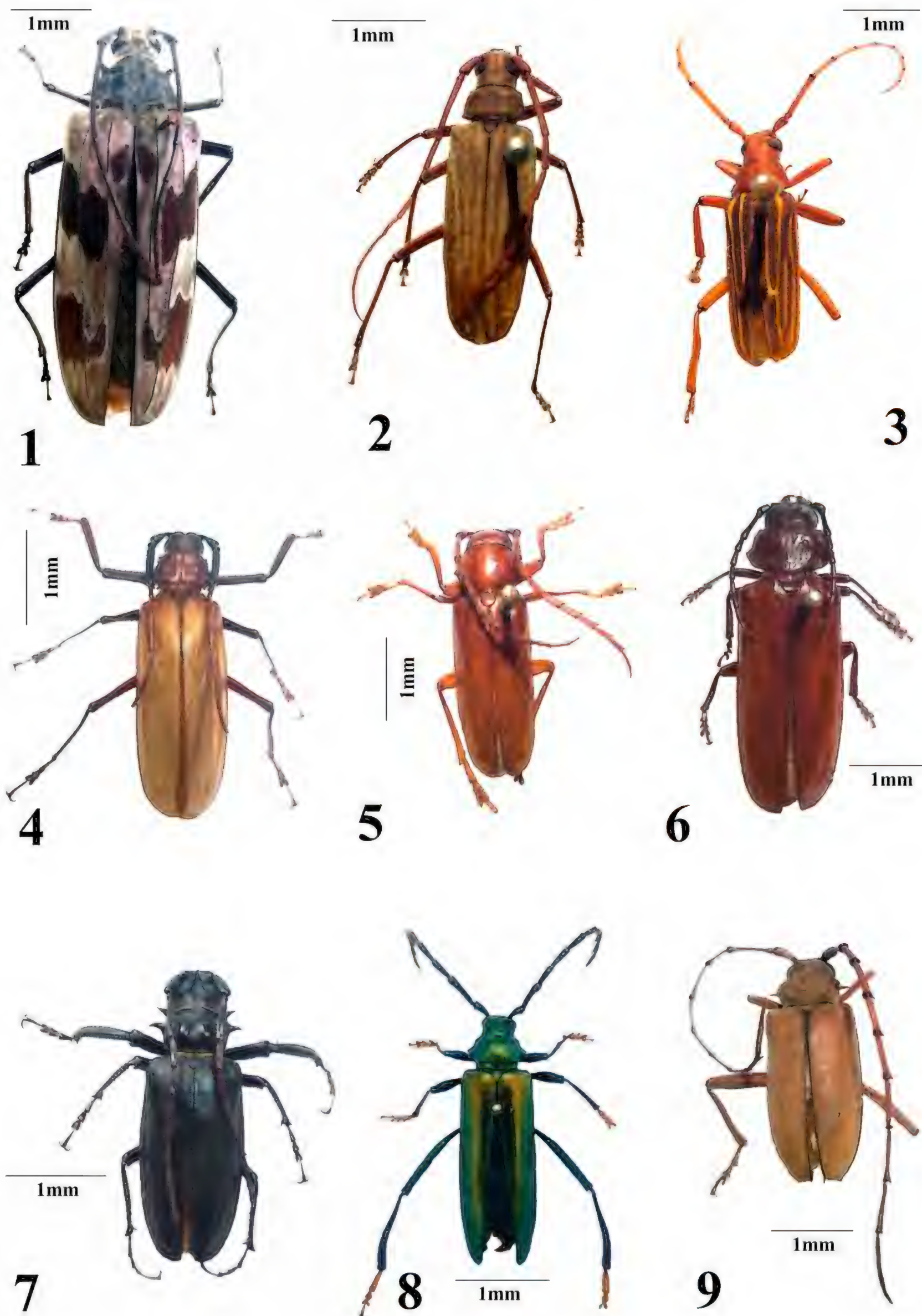
Antennae: 10 segments; Body length: 45 mm; Head: 17 mm.

Distribution: India: Arunachal Pradesh, Assam, Gujarat, Himachal Pradesh, Sikkim,

Tripura and West Bengal (Darjeeling);
Elsewhere: Borneo, China, Indonesia (Java,
Sumatra), Laos, Malaysia, Myanmar, Nepal,

Philippines, Sri Lanka, Thailand, Tibet and
Vietnam.

Remark: First record from Nagaland.



Figures 1-9: Long horn beetles of Lumami, Nagaland: 1. *Baralipton maculosum*; 2. *Nepiodes bowringi*; 3. *Nepiodes costipennis*; 4. *Bandar pascoei*; 5. *Dorysthenes buqueti*; 6. *Dorysthenes indicus*; 7. *Prionomma bigibbosum*; 8. *Aphrodisium cantori*; 9. *Neoplocaederus obesus*.

Tribe: Prionini Latreille, 1802

5. *Dorysthenes buqueti* (Guérin-Méneville, 1844)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-05(1)/2014).

Antennae: 11 segments; Body length: 11 mm; Head: 7 mm.

Distribution: India: Assam and Meghalaya; *Elsewhere:* Bangladesh, China (Guangxi, Yunnan), Indonesia (Java), Laos, Malaysia, Myanmar, Nepal and Thailand.

Remark: First record from Nagaland.

6. *Dorysthenes indicus* (Hope, 1831)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-06(1)/2014).

Antennae: 10 segments; Body length: 28 mm; Head: 10 mm.

Distribution: India: Arunachal Pradesh, Manipur, Meghalaya, Sikkim and West Bengal (Darjeeling); *Elsewhere:* Bhutan, China (Xizang) and Nepal.

Remark: First record from Nagaland.

7. *Prionomma bigibbosum* (White, 1853)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-07(3)/2014).

Antennae: 11 segments; Body length: 32 mm; Head: 10 mm.

Distribution: India: Assam, Manipur, Meghalaya and Sikkim; *Elsewhere:* Bangladesh, China (Yunnan, Hainan), Laos, Myanmar and Thailand.

Remark: First record from Nagaland.

Subfamily: Cerambycinae Latreille, 1802

Tribe: Callichromatini Swainson & Shuckard, 1840

8. *Aphrodisium cantori* (Hope, 1840)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-01(1)/2015).

Antennae: 10 segments; Body length: 34 mm; Head: 12 mm.

Distribution: India: Assam, Gujarat, Manipur, Meghalaya, Sikkim, Tripura, Tamil Nadu, Uttar Pradesh, Uttarakhand and West Bengal (Darjeeling); *Elsewhere:* Bangladesh, China (Guangxi), Laos, Myanmar, Nepal, Sri Lanka and Vietnam.

Remark: First record from Nagaland.

Tribe: Cerambycini Martins & Monné, 2002

9. *Neoplocaederus obesus* (Gahan, 1890)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-02(1)/2015).

Antennae: 10 segments; Body length: 20 mm; Head: 8 mm.

Distribution: India: Andaman Islands, Arunachal Pradesh, Assam, Maharashtra, Manipur, Nagaland, Odisha, Sikkim and West Bengal; *Elsewhere:* Laos, Myanmar, South China, Sri Lanka, Thailand and Vietnam.

Remark: Reported in Mitra *et al.*, 2016a, 2017.

10. *Trirachys indutus* (Newman, 1842)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-08(3)/2014/2020).

Antennae: 10 segments; Body length: 28 mm (head to bottom).

Distribution: India: Andaman & Nicobar Islands, Assam, Maharashtra and Tamil Nadu; *Elsewhere:* Borneo, China, Laos, Malaysia, Myanmar, Pakistan, Philippines (Mindanao, Luzon, Romblon, Sibuyan, Negros), Sri Lanka, Thailand and Vietnam.

Remark: First record from Nagaland.

Tribe: Callidiopini Lacordaire, 1868

11. *Ceresium zeylanicum* (White, 1855)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-09(1)/2014).

Antennae: 10 segments; Body length: 10 mm; Head: 4.5 mm.

Distribution: India: Assam and West Bengal; *Elsewhere:* Borneo, Laos, Myanmar, Philippines, Sri Lanka, Taiwan, Thailand and Vietnam.

Remark: First record from Nagaland.

Tribe: Hesperophanini Mulsant, 1839

12. *Stromatium longicorne* (Newman, 1842)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-03(1)/2015).

Antennae: 10 segments; Body length: 15 mm; Head: 12 mm.

Distribution: India: Assam and West Bengal; *Elsewhere:* Borneo, Cambodia, China, Japan, Laos, Malaysia, Myanmar, New Guinea, Philippines, Taiwan, Thailand and Vietnam.

Remark: First record from Nagaland.

Tribe: Xystrocerini Blanchard, 1845

13. *Oplatocera (Epioplatocera) oberthuri* (Gahan, 1906)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-04(1)/2015).

Antennae: 10 segments; Body length: 20 mm; Head: 10 mm.

Distribution: India: Sikkim and West Bengal (Darjeeling); *Elsewhere:* Borneo, Bhutan, China (Guangdong, Guangxi, Hunan, Shaanxi, Sichuan, Yunnan), Indonesia (Sumatra), Malaysia, Nepal, Philippines, Taiwan and Thailand.

Remark: First record from Nagaland.

14. *Xystrocera festiva* (Thomson, 1860)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-01(1)/2016).

Antennae: 10 segments; Body length: 26 mm; Head: 8 mm.

Distribution: India: Assam, Arunachal Pradesh, Meghalaya and Sikkim; *Elsewhere:* Borneo, China (Hainan, Yunnan), Indonesia (Java, Sumatra), Laos, Malaysia, Myanmar, Thailand and Vietnam.

Remark: First record from Nagaland.

15. *Xystrocera globosa* (Olivier, 1795)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-01(1)/2019).

Antennae: 10 segments; Body length: 11 mm; Head: 8 mm.

Distribution: India: Assam, Arunachal Pradesh, Gujarat, Karnataka, Maharashtra, Manipur, Madhya Pradesh, Mizoram, Tamil Nadu, Tripura and West Bengal (Darjeeling); *Elsewhere:* Australia, China, Comoros, Egypt, Korea, Hawaii, Indonesia (Java, Sulawesi, Sumatra, Timor), Israel, Laos, Malaysia, Madagascar, Marquesas, Mauritius, Myanmar, Nepal, New Caledonia, New Guinea, Pakistan, Philippines, Sri Lanka, Tahiti, Thailand, Taiwan and Vietnam.

Remark: First record from Nagaland.

Subfamily: Lamiinae Latreille, 1825

Tribe: Agapanthiini Mulstant, 1839

16. *Pothyne multivittipennis* (Breuning, 1950)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-10(1)/2014).

Antennae: 10 segments; Body length: 13 mm; Head: 5 mm.

Distribution: India: Central India and Tamil Nadu; *Elsewhere:* Data deficient.

Remark: First record from Nagaland.

Tribe: Batocerini Thomson, 1864

17. *Apriona germari* (Hope, 1831)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-12(1)/2014).

Antennae: 10 segments; Body length: 40 mm; Head: 10 mm.

Distribution: India: Arunachal Pradesh, Assam, Manipur, Meghalaya, Nagaland, Sikkim and Uttar Pradesh; *Elsewhere:* Bangladesh, Bhutan, Cambodia, China, Japan, Korea, Laos, Myanmar, Nepal, Pakistan, Sri Lanka, Taiwan and Vietnam.

Remark: Reported in Behere *et al.*, 2019.

18. *Batocera rubus* (Linnaeus, 1758)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/EI/LB-58(1)/2015).

Antennae: 10 segments; Body length: 31 mm; Head: 12 mm.

Distribution: India: Arunachal Pradesh, Assam, Gujarat, Meghalaya, Nagaland and Tamil Nadu; *Elsewhere:* Africa, Borneo, China, France, Indonesia (Java, Sumatra), Japan (Ryukyu: Okinawa), Korea, Laos, Malaysia, Myanmar, Philippines, Sri Lanka, Taiwan, Thailand and Vietnam.

Remark: Reported in Mozhui *et al.*, 2017.

19. *Batocera lineolata* (Chevrolat, 1852)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-11(3)/2014).

Antennae: 10 segments; Body length: 40 mm; Head: 15 mm.

Distribution: India: Assam, Meghalaya, Nagaland and Sikkim; *Elsewhere:* China, Japan, Korea, Myanmar and Taiwan.

Remark: Reported in Behere *et al.*, 2019.

20. *Batocera parryi* (Hope, 1845)

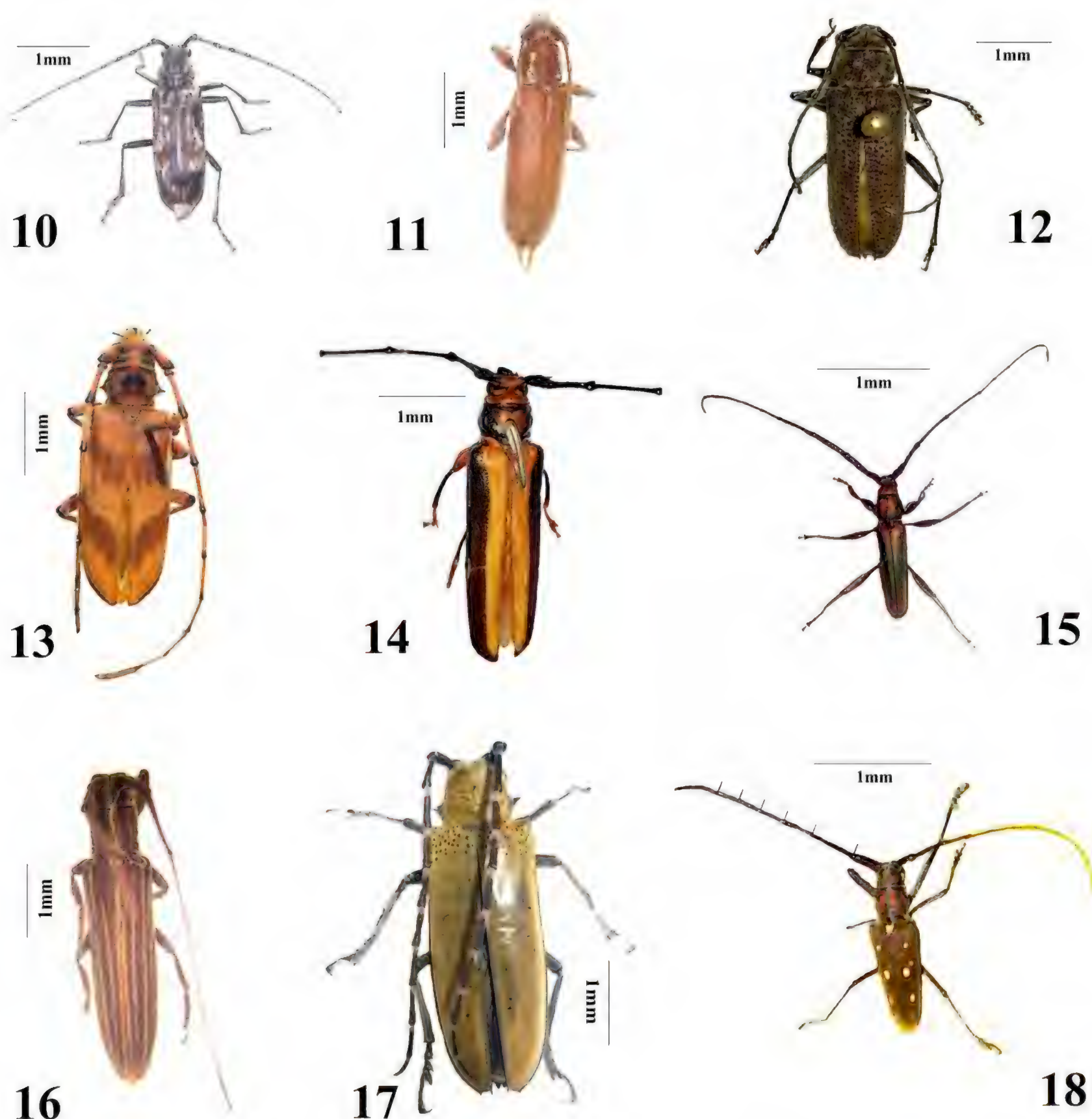
Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/EI/LB-57(1)/2015).

Antennae: 10 segments; Body length: 30 mm; Head: 10 mm.

Distribution: India: Arunachal Pradesh, Assam, Meghalaya, Nagaland, Sikkim and Tamil Nadu; *Elsewhere:* Borneo, China,

Indonesia (Java, Sumatra), Laos, Myanmar, Taiwan and Vietnam.

Remark: Reported in Mozhui *et al.*, 2017.



Figures 10-18: Long horn beetles of Lumami, Nagaland: **10.** *Trirachys indutus*; **11.** *Ceresium zeylanicum*; **12.** *Stromatium longicorne*; **13.** *Oplatocera (Epioplatocera) oberthuri*; **14.** *Xystrocera festiva*; **15.** *Xystrocera globosa*; **16.** *Pothyne multivittipennis*; **17.** *Apriona germari*; **18.** *Batocera rubus*.

Tribe: Ceroplesini Thomson, 1860

21. *Thysia wallichii* (Hope, 1831)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-05(1)/2015).

Antennae: 10 segments; Body length: 23 mm; Head: 10 mm.

Distribution: India: Arunachal Pradesh, Assam, Bihar, Meghalaya, Nagaland, Sikkim, Uttarakhand, Uttar Pradesh and West Bengal; *Elsewhere:* Borneo, China (Guangdong, Guangxi, Guizhou, Sichuan, Yunnan), Iran,

Laos, Malaysia, Myanmar, Nepal, Pakistan, Thailand and Vietnam.

Remark: Reported in Mitra *et al.*, 2016a, 2017.

Tribe: Eunidiini Téocchi *et al.*, 2010

22. *Eunidia lateralis* (Gahan, 1893)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-06(2)/2015).

Antennae: 10 segments; Body length: 6 mm; Head: 3 mm.

Distribution: India: Nagaland, South India (Tamil Nadu); *Elsewhere:* Cambodia, China (Hainan, Yunnan), Nepal, South Korea, Thailand and Vietnam.

Remark: Reported in Behere *et al.*, 2019.

Tribe: Lamiini Latreille, 1825

23. *Anoplophora stanleyana* (Hope, 1839)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/EI/LB-56(1)/2015).

Antennae: 10 segments; Body length: 21 mm; Head: 9 mm.

Distribution: India: Assam and Sikkim; *Elsewhere:* China, Laos, Myanmar and Thailand.

Remark: First record from Nagaland.

Tribe: Mesosini Mulsant, 1839

24. *Coptops leucostictica* (White, 1858)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-07(1)/2015).

Antennae: 10 segments; Body length: 15 mm; Head: 7 mm.

Distribution: India: Arunachal Pradesh, Assam, Mizoram, Nagaland, Sikkim and West Bengal (Darjeeling); *Elsewhere:* Cambodia, China, Indonesia, Laos, Malaysia, Myanmar, Thailand and Vietnam.

Remark: Reported in Mitral *et al.*, 2016a, 2017.

25. *Mesosa (Perimesosa) binigrovittipennis* (Breuning, 1968)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-08(1)/2015).

Antennae: 8 segments; Body length: 12 mm; Head: 5 mm.

Distribution: India: Arunachal Pradesh, Sikkim and West Bengal (Darjeeling); *Elsewhere:* Bhutan and Vietnam.

Remark: First record from Nagaland.

Tribe Monochamini Gistel, 1856

26. *Aristobia reticulator* (Fabricius, 1781)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-02(1)/2016).

Antennae: 10 segments; Body length: 20 mm; Head: 7 mm.

Distribution: India: Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura; *Elsewhere:*

Bangladesh, China, Laos, Myanmar, Nepal, Thailand and Vietnam.

Remark: Reported in Mitral *et al.*, 2016a, 2017; Behere *et al.*, 2019.

27. *Blepephaeus succinator* (Chevrolat, 1852)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-09(1)/2015).

Antennae: 10 segments; Body length: 17 mm; Head: 7 mm.

Distribution: India: Assam and West Bengal; *Elsewhere:* Bangladesh, China, Laos, Malaysia, Myanmar, Nepal, Taiwan, Thailand and Vietnam.

Remark: First record from Nagaland.

28. *Epepeotes uncinatus* (Gahan, 1888)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-10(2)/2015).

Antennae: 10 segments; Body length: 20 mm; Head: 10 mm.

Distribution: India: Arunachal Pradesh, Karnataka, Kerala and West Bengal; *Elsewhere:* Bhutan, China, Laos, Myanmar, Nepal, Sri Lanka and Vietnam.

Remark: First record from Nagaland.

29. *Monochamus bimaculatus* (Gahan, 1888)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-13(1)/2014).

Antennae: 10 segments; Body length: 10 mm; Head: 4 mm.

Distribution: India: Arunachal Pradesh, Uttar Pradesh, Sikkim and West Bengal; *Elsewhere:* China, Laos, Malaysia, Myanmar, Nepal, Taiwan, Thailand and Vietnam.

Remark: First record from Nagaland.

30. *Pseudonemophas versteegii* (Ritsema, 1881)

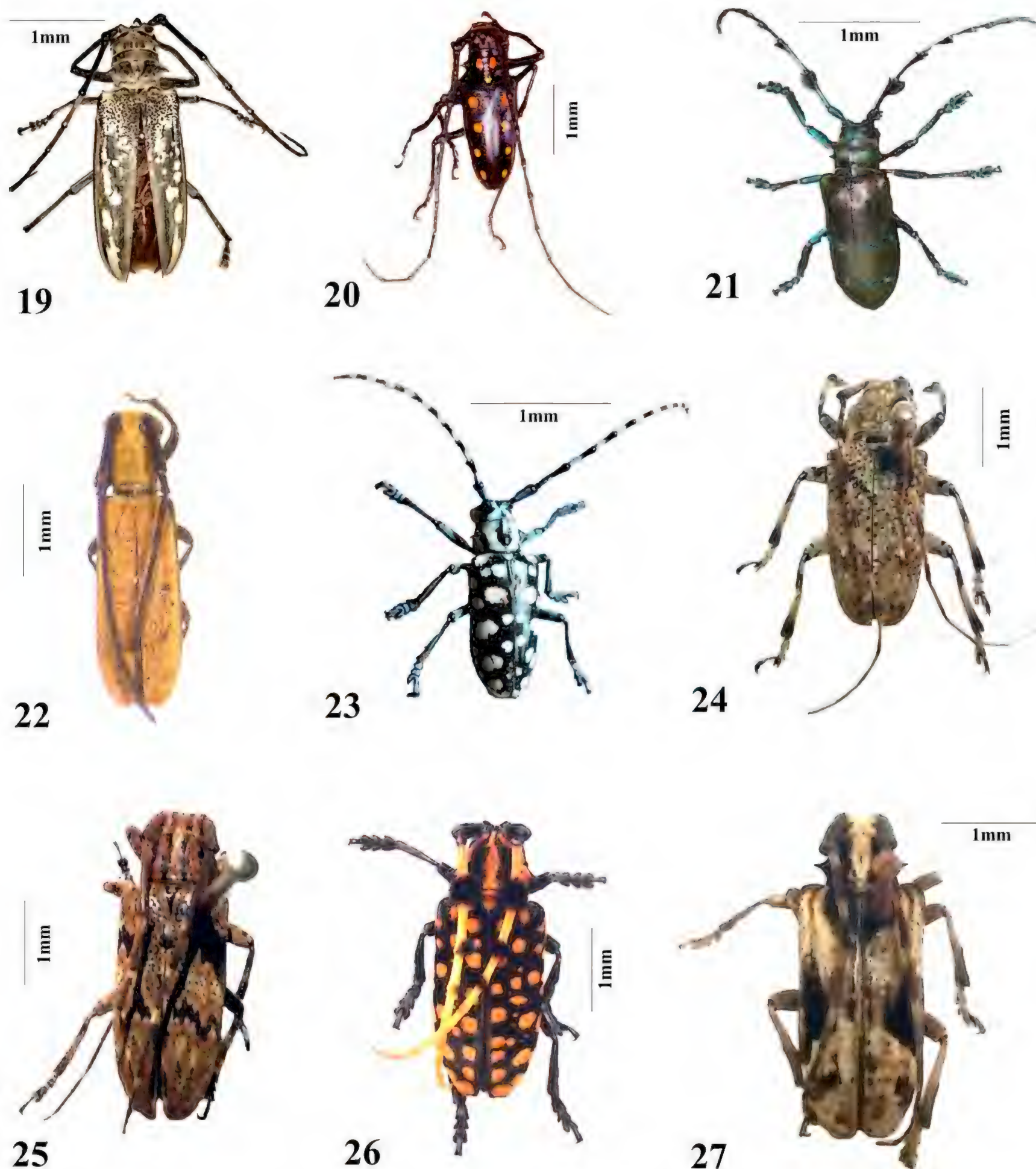
Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-01(2)/2017/2020).

Antennae: 11 segments; Body length: 22 mm; Head: 10 mm.

Distribution: India: Arunachal Pradesh, Assam, Mizoram, Nagaland, Sikkim and West Bengal; *Elsewhere:* Laos, Myanmar, Nepal, Subtropical China, Indonesia (Sumatra), Taiwan, Thailand and Vietnam.

Remark: Reported in Mitral *et al.*, 2017; Behere *et al.*, 2019.

A checklist of long horn beetles of Lumami, Zunheboto District, Nagaland



Figures 19-27: Long horn beetles of Lumami, Nagaland: **19.** *Batocera lineolata*; **20.** *Batocera parryi*; **21.** *Thysia wallichii*; **22.** *Eunidia lateralis*; **23.** *Anoplophora stanleyana*; **24.** *Coptops leucostictica*; **25.** *Mesosa (Primesosa) binigrovittipennis*; **26.** *Aristobia reticulator*; **27.** *Blepephaeus succintor*.

Tribe: Petrognathini Blanchard, 1845

31. *Ithocritus ruber* (Hope, 1839)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-04(2)/2016).

Antennae: 10 segments; Body length: 20 mm; Head: 10 mm.

Distribution: India: Assam, Meghalaya and Sikkim; *Elsewhere:* Bangladesh, Myanmar and Vietnam.

Remark: First record from Nagaland.

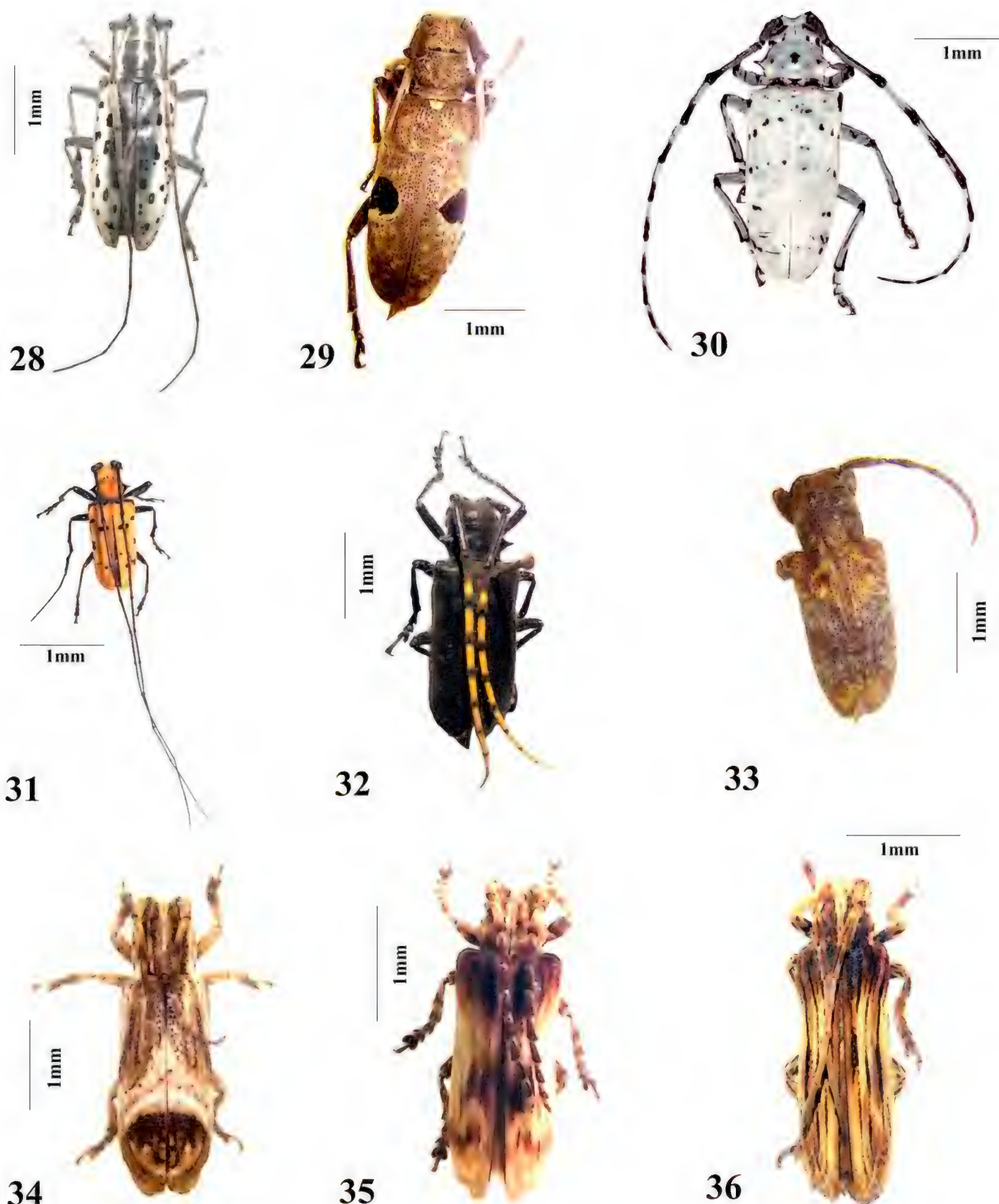
32. *Pseudapriona flavoantennata* (Breuning, 1936)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-03(1)/2016).

Antennae: 10 segments; Body length: 20 mm; Head: 7 mm.

Distribution: India: Arunachal Pradesh, Himalayan India, Meghalaya, Nagaland and Peninsular India; *Elsewhere:* Myanmar and Tibet.

Remark: Reported in Mitral *et al.*, 2017.



Figures 28-36: Long horn beetles of Lumami, Nagaland: **28.** *Epepeotes unicatus*; **29.** *Monochamus bimaculatus*; **30.** *Pseudonemophas versteegii*; **31.** *Ithocritus ruber*; **32.** *Pseudapriona flavoantennata*; **33.** *Pterolophia multifasciculata*; **34.** *Sthenias franciscana*; **35.** *Thylactus simulans*; **36.** *Xylorhiza adusta*.

Tribe: Pteropliini, Thomson, 1860

33. *Pterolophia multifasciculata* (Pic, 1926)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-11(1)/2015).

Antennae: 10 segments; Body length: 8 mm; Head: 3 mm.

Distribution: India: Data deficient; *Elsewhere:* Cambodia, China, Thailand and Vietnam.

Remark: First record from Nagaland.

34. *Sthenias franciscana* (Thomson, 1865)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-05(1)/2016).

Antennae: 10 segments; Body length: 12 mm; Head: 5 mm.

Distribution: India: Sikkim; *Elsewhere:* Indonesia, Malaysia and Thailand.

Remark: First record from Nagaland.

Tribe: Xylorhizini Lacordaire, 1872

35. *Thylactus simulans* (Gahan, 1890)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-02(3)/2017).

Antennae: 10 segments; Body length: 22 mm; Head: 6 mm.

Distribution: India: Arunachal Pradesh, Sikkim and West Bengal (Darjeeling); *Elsewhere:* China, Laos, Myanmar, Thailand and Vietnam.

Remark: First record from Nagaland.

36. *Xylorhiza adusta* (Wiedemann, 1819)

Material examined: District Zunheboto, Village Lumami (Regd. No. NU/ZOO/LB-03(2)/2017).

Antennae: 10 segments; Body length: 25 mm; Head: 10 mm.

Distribution: India: Arunachal Pradesh, Meghalaya, Sikkim and West Bengal; *Elsewhere:* Borneo, Cambodia, China, Indonesia (Sumatra), Laos, Malaysia, Myanmar, Nepal, Philippines, Sri Lanka, Thailand and Vietnam.

Remark: First record from Nagaland.

Discussions

A total of 36 long horn beetles were recorded from Lumami, of which 23 species were found to be new record to the state of Nagaland. Of these, the subfamily Lamiinae recorded the maximum number with 21 species, followed by Cerambycinae with a total of 8 species and Prioninae with a total of 7 species. Characterized by the typical presence of long antennae (varies among species), short legs and a flat face, Prioninae, Cerambycinae and Lamiinae are three much diversified subfamily comprising many genera showing variations in sizes and colours. They are serious pests causing extreme damages to trees especially on the trunk portion of the body and are known to cause damages to untreated timber. However, even though they are considered as pest, larvae and pupae of some long horn beetles for e.g., *Batocera rubus* and *Batocera parryi* are considered as delicacies by the different ethnic groups in Nagaland (Mozhui *et al.*, 2017). Depending on the species, the long horn beetles are found throughout the year. For instance, *Pseudonemophas versteegii* were collected mostly in the month of May, *Thylactus simulans* mostly in the month of June while *Trirachys indutus* were mostly collected in the

month of February. The present study led to the firm belief that the region is rich with Cerambycidae diversity and further extensive research and intensive sampling, may lead to even more discoveries of both little known and unknown taxa under this group.

Funding: This research received no external funding.

Conflict of Interest: The authors declare no conflict of interest.

References

- Agarwala, B.K. and Bhattacharjee, P.P. 2012. Long-horned beetles (Coleoptera: Cerambycidae) and tortoise beetles (Chrysomelidae: Cassidinae) of Tripura, northeastern India with some new additions. *Journal of Threatened Taxa* 4(13): 3223-3227.
- Anonymous. 2005. Fauna of Nagaland, State Fauna Series 12. Kolkata: Zoological Survey of India. 620pp.
- Beeson, C.F.C. and Bhatia, B.M. 1939. On the biology of the Cerambycidae (Coleoptera). *Indian Forest Records* 5(1): 1-235.
- Behere, G.T., Firake, D.M. and Burange, P.S. 2019. An inventory (Database): Long horn beetles of North-eastern and Western Himalaya. <http://www.kiran.nic.in/.56p>.
- Breuning, S. 1964. Revision der Apomecynini der asiatisch-australischen Region. *Entomologische Abhandlungen Museum fur Tierkunde in Dresden* 30: 528.
- Chandra, K., Biswas, B. and Kushwaha, S. 2015. Diversity of Pyrrhocoroidea (Hemiptera: Heteroptera) of Madhya Pradesh, India. *Munis Entomology & Zoology* 10(1): 169-171.
- Cherepanov, A.I. 1990. Cerambycidae of Northern Asia Vol. 3. Lamiinae Part 1. New Delhi: Amerind Publishing Co. Pvt. Ltd. 300 pp.
- Gahan, C.J. 1906. The Fauna of British India including Ceylon and Burma. Coleoptera 1. Cerambycidae. London: Taylor and Francis. 329 pp.
- Kariyanna, B., Mohan, M., Gupta, R. and Vitali, F. 2017. The checklist of longhorn beetles (Coleoptera: Cerambycidae) from India. *Zootaxa* 4345(1): 001-317.
- Komiya, Z. and Drumont, A. 2010. A revision of the genus *Nepiodes* (Coleoptera,

- Cerambycidae, Prioninae) (Revisional studies of the genus *Megopis* sensu LAMEERE, 1909-10). Elytra, Tokyo 38(2): 169-192.
- Mitra, B., Bhaumik, S., Chakraborti, U. and Mallick, K. 2017. An update on the diversity, distribution and zoo-geographical notes on Longhorn Beetles (Cerambycidae: Coleoptera) of North-East India. Biological Forum- an International Journal 9(2): 61-80.
- Mitra, B., Das, P., Chakraborti, U. and Mallick, K. 2016a. Long horn beetles (Cerambycidae: Coleoptera) of Nagaland, India. Journal of Global Biosciences 5(4): 3963-3969.
- Mitra, B., Das, P., Chakraborti, U., Mallick, K. and Majumder, A. 2016b. Long horn beetles (Cerambycidae: Coleoptera) of Meghalaya with eight new records. The Journal of Zoology Studies 3(4): 39-47.
- Mitra, B., Das, P., Chakraborti, U., Mallick, K. and Majumder, A. 2016c. New records of long horn beetles (Cerambycidae: Coleoptera) from Manipur state with checklist. The Journal of Zoology Studies 3(1): 19-26.
- Monne, M.L., Monne, M.A. and Wang, Q. 2017. General morphology, classification and biology of Cerambycidae. In: Q. Wang (ed.) Cerambycidae of the world: biology and pest management, Boca Raton, FL: CRC Press. 76pp.
- Mozhui, L., Kakati, L.N. and Changkija, S. 2017. A study on the use of insects as food in seven tribal communities in Nagaland, Northeast India. Journal of Human Ecology 60(1): 42-53.
- Mukhopadhyay, P. and Biswas, S. 2000a. Coleoptera: Cerambycidae. In: Director, Zoological Survey of India (eds.). State Fauna Series 4, Fauna of Meghalaya Part 5, Zoological Survey of India, 41-67.
- Mukhopadhyay, P. and Biswas, S. 2000b. Coleoptera: Cerambycidae. In: Director, Zoological Survey of India (eds.) State Fauna Series 7, Fauna of Tripura Part 3, Zoological Survey of India, 139-142.
- Mukhopadhyay, P. and Halder, S.K. 2004. Insecta: Coleoptera: Cerambycidae. In: Director, Zoological Survey of India (eds.) State Fauna Series 10, Fauna of Manipur Part 2, Zoological Survey of India, 421-431.
- Shylesha, A.N., Thakur, N.S.A. and Ramchandra. 2000. Incidence of litchi trunk borer, *Aristobia testudo* Voet (Coleoptera: Lamiidae) on guava in Meghalaya. Pest Management in Horticultural Ecosystems 6(2): 156-157.

An updated checklist of Silverfish fauna (Insecta: Apterygota: Zygentoma) of India

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Abstract

An updated checklist of Zygentoma fauna from India is provided herewith. Altogether 22 species under 15 genera grouped in two families with their distribution records in India plus 2 species inquirenda are listed.

Keywords: Silverfish, Zygentoma, Checklist, Lepisma, India.

Received: 6 February 2020; Revised: 30 December 2020; Online: 31 December 2020

Introduction

The order Zygentoma (commonly known as silverfish), represent one of the earliest insect. They are considered to be the sister group of the winged insects (Blanke *et al.*, 2014). The name Zygentoma Börner, 1904 is used at present by all the taxonomists working on this group. The name “Thysanura” was originally created for an order that included, the Zygentoma, the Microcoryphia, the Diplura at different times, and even the Collembola (Gaju-Ricart *et al.*, 2015). The first silverfish described, was the European lepismatid household pest *Lepisma saccharina* Linnaeus, 1758. Gervais (1844) described the first soil-dwelling Nicoletiidae, *Nicoletia phytophila*, considering its elongate form, without scales and eyes. So far, 625 species have been described worldwide under 5 families with 148 genera (Smith, 2018).

Escherich (1903) described the first Indian Lepismatid *Lepisma indica* from Matheran, Maharashtra, later Mendes (1988) have considered this as species inquirenda. Another species *Lepisma devadasi* Sukumar & Livingstone, 1993 has also been considered as species inquirenda (Smith, 2018). Escherich (1905, 1906), Silvestri (1913, 1935, 1938), Paclt (1961, 1967), Joseph & Mathad (1963), Hazra (1980, 1993, 1996, 2000, 2004, 2012), Mendes (1989, 1992), Hazra and Mandal (2004a, b & 2010) contributed to the knowledge of Indian Zygentoma. Subsequently

Hazra and Mandal (2007) published a pictorial handbook of Indian Thysanura. Mandal (2010) published a check list of Indian Thysanura.

The poorly known Indian fauna of Zygentoma is represented by 22 species under 2 families with 15 genera within which the family Lepismatidae represents a total of 12 species belonging to 8 genera plus 2 species inquirenda. The aim of the present communication is to provide an up to date list of Zygentoma fauna of India with distribution records.

Updated Checklist of Zygentoma from India

The detail updated checklist is provided herewith. Distribution records of species are based on published work of earlier authors.

Class Insecta

Order Zygentoma Börner, 1904

Family Lepismatidae (Latreille, 1802)

Subfamily Acrotelsatinae Mendes, 1991

Genus *Acrotelsa* Escherich, 1905

1. *Acrotelsa collaris* (Fabricius, 1793)

Distribution: Andhra Pradesh, Uttarakhand, West Bengal

Subfamily Ctenolepismatinae Mendes, 1991

Genus *Acrotelsella* Silvestri, 1935

2. *Acrotelsella wygodzinsky* (Hazra, 1980)

Distribution: West Bengal

Genus *Ctenolepisma* Escherich, 1905

Subgenus *Ctenolepisma* Escherich, 1905

3. *Ctenolepisma* (*Ctenolepisma*) *alticola* Silvestri, 1935

Distribution: Jharkhand, Ladakh

4. *Ctenolepisma* (*Ctenolepisma*) *boettgerianum* Paclt, 1961

Distribution: Chhattisgarh, Gujarat, Madhya Pradesh, Maharashtra

5. *Ctenolepisma* (*Ctenolepisma*) *longicaudatum* Escherich, 1905

Distribution: Andaman & Nicobar Island, Andhra Pradesh, Manipur, Uttar Pradesh, Uttarakhand, Tripura, West Bengal

6. *Ctenolepisma* (*Ctenolepisma*) *nigra* (Oudemans, 1890)

Distribution: West Bengal

7. *Ctenolepisma* (*Ctenolepisma*) *tripurensis* Hazra, Biswas & Mitra, 2000

Distribution: Tripura

Genus *Thermobia* Bergroth, 1890

8. *Thermobia domestica* (Packard, 1873)

Distribution: Mandapam (Tamil Nadu)

Subfamily Lepismatinae (Latreille, 1802)

Genus *Afrolepisma* Mendes, 1981

9. *Afrolepisma nigra* (Silvestri, 1913)

Distribution: Odisha

Genus *Lepisma* Linnaeus, 1758

10. *Lepisma saccharina* Linnaeus, 1758

Distribution: Sikkim, Uttarakhand

Genus *Tricholepisma* Paclt, 1967

11. *Tricholepisma gravelyi* (Silvestri, 1913)

Distribution: West Bengal

Genus *Xenolepisma* Mendes, 1981

12. *Xenolepisma subnigra* (Silvestri, 1938)

Distribution: Tamil Nadu

Family Nicoletiidae (Lubbock, 1873)

Subfamily Atelurinae Remington, 1954

Tribe Atelurini Remington, 1954

Genus *Assmuthia* Escherich, 1906

13. *Assmuthia inermis* Escherich, 1906

Distribution: Maharashtra

14. *Assmuthia spinosissima* Escherich, 1906

Distribution: Maharashtra

Genus *Atelurodes* Silvestri, 1916

15. *Atelurodes typhloponis* (Silvestri, 1913)

Distribution: Uttarakhand, West Bengal

Genus *Bharatatelura* Mendes, 1992

16. *Bharatatelura malabarica* Mendes, 1992

Distribution: Goa, Haryana, Delhi, Maharashtra.

Genus *Neatelura* Joseph & Mathad, 1963

17. *Neatelura yellapurensis* Joseph & Mathad, 1963

Distribution: Karnataka

Genus *Platystylea* Escherich, 1906

18. *Platystylea barbifer* Escherich, 1906

Distribution: Maharashtra

Tribe Atopatelurini Mendes, 2012

Genus *Pseudogastrotheus* Mendes, 2003

19. *Pseudogastrotheus indicus* (Silvestri, 1913)

Distribution: Odisha, Karnataka

20. *Pseudogastrotheus palpiseta* (Silvestri, 1916)

Distribution: Karnataka

Subfamily Coletiniinae Mendes, 1988

Genus *Lepidospora* Escherich, 1905

Subgenus *Lepidospora* Escherich, 1905

21. *Lepidospora* (*Lepidospora*) *ceylonica* Silvestri, 1911

Distribution: Uttarakhand

22. *Lepidospora* (*Lepidospora*) *notabilis* Silvestri, 1913

Distribution: Uttar Pradesh*

Species inquirenda (2 spp.)

Lepisma devadasi Sukumar & Livingstone, 1993

Lepisma indica Escherich, 1903

*Remarks: Mendes (1991) listed the species *Lepidospora* (*Lepidospora*) *notabilis* Silvestri, 1913 occurred from Uttar Pradesh, India. But Silvestri (1913) describe the species based on the collection from Myanmar (E. side of Dawna Hills, L. Burma).

Acknowledgements

The authors express their sincere thanks to MOEF & CC, Govt. of India, New Delhi for funding the project under AICOPTAX scheme to the Senior author. Thanks are also due to Dr. Kailash Chandra, Director, Zoological Survey of India, Kolkata for providing facilities for the present study

and to Dr. A.A. Mao Director Botanical Survey of India, Kolkata and nodal officer of the project for extending help as when required. Authors are thankful to Dr. Gautam Kundu, Principal, Vidyasagar College, Kolkata for providing the Laboratory facilities.

References

- Blanke, A., Koch, M. and Misof, B. 2014. Head morphology of *Tricholepidion gertschi* indicates monophyletic Zygentoma. *Frontiers in Zoology* 11(16): 1-19pp.
- Börner, V.C. 1904. Zur Systematik der Hexapoda. *Zoologischer Anzeiger* 27: 523-524.
- Escherich, K. 1903. Contribution to the knowledge of Thysanura. *Zoologischer Anzeiger* 26(697): 345-366.
- Escherich, K. 1905. Das System der Lepismatiden. *Zoologica* (Stuttgart) 43: 1-164.
- Escherich, K. 1906. Contribution to the Knowledge of the Thysanura. *Zoologischer Anzeiger* 741-744.
- Gaju-Ricart, M., Molero-Baltanás, R. and Bach de Roca, C. 2015. Forward without wings: Current progress and future perspectives in the study of Microcoryphia and Zygentoma. *Soil Organisms* 87(3): 183–195.
- Gervais, P. 1844. Thysanoures. *In*: Walckenaer (ed.) *Histoire Naturelle des Insectes. Aptères*. Vol. 3. Paris: Librairie Encyclopédique de Roret 377–456 pp.
- Hazra, A.K. 1980. On a New Species of Styliifera (Lepismatidae: Thysanura: Insecta) from India. *Bulletin Zoological Survey of India, Kolkata* 2 (2 & 3): 187-191.
- Hazra, A.K. 1993. Insecta: Apterygota: Thysanura. *In*: Fauna of West Bengal, State Fauna Series, Zoological Survey of India, Kolkata 3(Part-4): 1-17 pp.
- Hazra, A.K. 1996. Insecta: Apterygota: Thysanura. *In*: Fauna of Delhi, State fauna Series, Zoological Survey of India, Kolkata 6: 145-146 pp.
- Hazra, A.K., Biswas, M. and Mitra, S.K. 2000. Insecta: Apterygota: Thysanura. *In*: Fauna of Tripura, State Fauna Series, Zoological Survey of India, Kolkata 7(2): 123-129 pp.
- Hazra, A.K. 2004. Insecta: Apterygota: Thysanura. *In*: Fauna of Manipur, State Fauna Series, Zoological Survey of India, Kolkata 10: 45-50 pp.
- Hazra, A.K. 2012. Fauna of Andaman and Nicobar Islands, State Fauna Series, (Published by the Director, Zoological Survey of India, Kolkata) 19(Part-1): 15-18 pp.
- Hazra, A.K. and Mandal, G.P. 2004a. Insecta: Apterygota: Thysanura. *In*: Fauna of Sikkim, State Fauna Series, Zoological Survey of India, Kolkata 9(2): 101-107 pp.
- Hazra, A.K. and Mandal, G.P. 2004b. Studies on the diversity & Distribution of Thysanura from Himachal Pradesh with Zoogeographical relationship. *In*: Orion Press International Vol. III: 505-509 pp.
- Hazra, A.K. and Mandal, G.P. 2007. Pictorial Handbook on Indian Thysanura. Kolkata: Zoological Survey of India 1-43 pp.
- Hazra, A.K. and Mandal, G.P. 2010. Fauna of Uttarakhand, State Fauna Series. Kolkata: Zoological Survey of India. 18(part-2) 13-16 pp.
- Joseph, K.J. and Mathad, S.B. 1963. A New Genus of Termitophilous Atelurinae (Thysanura: Nicoletidae) from India. *Insectes Sociaux*, Paris Volume X, 1963, n°4, 379-386.
- Linnaeus, C. 1758. *Systema Naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. Editio decima, reformata [10th revised edition], Laurentius Salvius: Holmiae vol. 1: 824 pp.
- Mandal, G.P. 2010. Checklist of Thysanura (Microcoryphia and Zygentoma) from India. Accessed online at <http://www.zsi.gov.in>
- Mendes, L.F. 1988. Revisão do género *Lepisma* Lin., 1758 s.lat. (Zygentoma, Lepismatidae). *In*: Boletim da Sociedade Portuguesa de Entomologia (Suppl.) 2: 10 p.
- Mendes, L.F. 1989. On The Zoogeographic Affinities of the thysanurans (Microcoryphia and Zygentoma) from India. *In*: G.K. Veeresh *et al.* (eds.) *Advances in management and Conservation of Soil fauna*. New Delhi: Oxford & IBH Publishing Co. Pvt. Ltd. 15-24 pp.
- Mendes, L.F. 1992. Zygentoma from the Oriental region and Indonesia – On some

- new and poorly known Ateluridae. Records Zoological Survey of India 90(1-4): 211-238.
- Paclt, J. 1961. Borstenschwanze (Ins. Thysanura) des Senckenberg-Museums. Senckenbergiana Biologica 42(1-2): 77-79.
- Paclt, J. 1967 Thysanura. Fam. Lepidotrichidae, Maindroniidae, Lepismatidae. In: P. Wytsman, Genera Insectorum, fase 218e: 1-86 pp.
- Smith, G.B. 2018. The Contribution of Silverfish (Insecta: Zygentoma) to Australian Invertebrate Biodiversity and Endemism. Ballarat: Ph.D thesis published by the Federation University Australia: 1-75pp.
- Silvestri, F. 1913. On some Thysanura in the Indian Museum. Records of the Indian Museum 9: 61-62.
- Silvestri, F. 1935. In: P.C. Viesser *et al.* Wissenschaftlich Ergebnisse der Niederlandischen Expedition den Karakorum and die angrenzenden Gebiete 1922-1925 and 1929-1930 Leipzig 1: 205-207 pp.
- Silvestri, F. 1938. Description of a new myrmicophilous *Lepisma* (Thysanura) from India. Records of the Indian Museum 40: 143-145.
- Sukumar, S. and Livingstone, D. 1993. A new species of *Lepisma* Linne from the Palghat Gap, South India (Thysanura: Lepismatidae). Journal of Entomological Research 17(3): 189-194.